Vol. XIII. — No. 7. July 1931.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[621 .131.3 (.438)]

A description of the method of carrying out locomotive tests on the Polish State Railways,

by Professor A. CZECZOTT,
Chief Engineer of the Testing Department,
Graduate of the Ways and Communications Institute at Saint-Petersburg.

Figs. 1 to 22, pp. 576 to 602.

CONTENTS.

I. — Foreword.
Organisation of the Testing Department.
General method of testing.
Publication of the results.
II. — *Method of testing boilers.*
Programme.
Remarks on the method of calculating the steam production.
Method of making a test.
Preparation of the heat balance sheet.
Analysis of the gases.
III. — *Application to the test of a smoke consuming device.*
Description of the device and the way it works.
Programme of the tests.
Results, their graphical representation. Discussion.
Heat balance sheet.
Smoke consuming effect.
IV. — *Supplementary tests.*

I. — Foreword.

Organisation of the Testing Department.

The Testing Department of the Polish State Railways is responsible for carrying out the various tests to be made with the stock in general and the locomotives in particular, in order to collect the data needed in fixing the loads and speeds of the trains, and also for investigating new

Fig. 1. — Test train, Polish Ministry of Communications.

inventions submitted to the Ministry. It is in addition responsible for determining scientifically and practically, the qualities of the different coals submitted. Besides the above work, the results of which can be made use of immediately, it has on occasion to undertake investigations of a more general scope, such as for example, an enquiry into the variation in production of steam with the speed of the locomotive.

In order to cover the above work, the Testing Department has at its disposal the following special equipment :

a six-wheeled dynamometer car;

four passenger vehicles fitted out for the test staff (office, kitchen, sleeping quarters);

a brake van fitted with instruments for the analysis of the combustion gases;

fifty-two wagons with ballast weights and fitted with the Westinghouse brake;

656.06
INT
v. 13 cop 2

a workshop van for repairing the measuring instruments.

This wagon is fitted with a petrol motor and a dynamo which supplies power to drive the machine tools and to light the train.

General method of testing.

Whereas in carrying out tests of stationary engines it is easy to make accurate measurements of the consumption, of the power, and of the efficiency and

Fig. 2. — Friction drive for the diagram paper roll.

to know exactly to what working conditions these measurements correspond, because it is possible to maintain uniform conditions over a sufficiently long period, this is not the case in making trials out on the line as the running conditions are then changing all the time. In the United States, special locomotive testing plants have been built so that locomotives can be tested under different conditions which can be maintained rigorously constant, and for as long as may be desired.

As we have not such a test plant at our disposal, we were obliged, seeing we wished to obtain more accurate data than in the past, to look for a method of carrying out the tests in which the locomotive could be worked for several hours at a well determined and rigorously constant regime.

Under this condition alone, can we be

949188

certain of making sufficiently accurate measurements and be sure from one test to another of only altering the value of one alone of the variables and thereby of ascertaining the true effect of the various working factors on the efficiency of the locomotive, on its power, etc.

The limiting factors which govern the rate of working of the locomotives, and the values of which are fixed before each test are :

the running speed,
the cut-off in the cylinders,
the steam chest pressure,
the blast pipe opening.

All these factors being constant, the locomotive works at *a constant indicated power*.

Such conditions can only be maintained with a given train load, on a straight line of constant gradient, a line which does not exist because amongst other reasons, the test must last several hours if the records are to be exact.

In order to realise these conditions in practice we conceived the idea of incorporating in the rake coupled to the locomotive, a second locomotive known as the « regulator », the sole duty of which was to maintain the speed of the train constant. The weight of the train is fixed so that the test locomotive developing a given power, the regulator locomotive has to exert on the level no power, neither accelerative nor retardative, to maintain the fixed constant speed.

On the up gradients the regulator locomotive assists the trial locomotive and on the down, the regulator locomotive, as well as a number of wagons, are braked.

In order to facilitate the work of making the tests, they are made as far as possible on lines on the level, with little traffic and on which long distances separate the stations.

Publication of the results.

The results of the Testing Department's work are published in the form of either short notices with diagrams showing in a condensed form the information which can be used directly for calculations, or as detailed reports. The results of tests carried out to ascertain the value of new contrivances are generally published in the latter form. In Chapter III, we give, as an example, a report regarding a smoke consuming device.

II. — Method of testing boilers.

Programme.

The tests to be described later on were carried out concurrently with other analogous tests over an almost level section. Each run was 145 km. (90 miles) long and lasted about six hours which was sufficient to allow us to make three successive tests corresponding to three well defined rates of output of the boiler.

The first test (I) was made at a speed of 20 km. (12.4 miles) per hour with 10 % cut-off and lasted about two hours.

The second test (II) was made at a speed of 30 km. (18.6 miles) per hour with 20 % cut-off and lasted an hour and a half.

The third (III) was made at a speed of 40 km. (24.8 miles) per hour with 30 % cut-off and lasted an hour.

The regulator was full open all the time and the boiler pressure was maintained at 13 kgr./cm² (184.9 lb. per sq. inch).

The leading dimensions of the locomotive used during the tests were as follows :

Class		Type 140 Tr. 12
Adhesive weight		58 t. (57.1 Engl. tons).
Total weight		68 t. (66.9 Engl. tons).
Grate area	R =	3.87 m² (41.6 sq. feet).
Heating surface (1). Actual	H =	166.70 m² (1 795 sq. feet).
Superheater	h =	38.30 m² (413.3 sq. feet).
Total		205.00 m² (2 217 sq. feet).
Boiler pressure		13 kgr./cm² (184.9 lb. per sq. inch.)
Diameter of wheels	D =	1 260 mm. (4 ft. 1 19/32 in.)
Simple expansion, two cylinders		570×632 (22 7/16 in. × 24 55/64 in)
Coefficient $p \frac{d^2 l}{D}$ = 21 287.		
Maximum tractive effort corresponding to the adhesive weight		12 300 kgr. (27 120 lb).
6-wheeled tender:		
Empty weight		17 t (16.7 Engl. tons).
Water		16 m³ (3 520 Br. gallons).
Coal		7 t. (6.9 Engl. tons).
Loaded weight		40 t. (39.4 Engl. tons).
Engine and tender.		
Total weight		108 t. (106.3 Engl. tons)
Total wheel-base		13.700 m. (44 ft. 11 3/8 in.).
Length over buffers		17.540 m. (57 ft. 6 9/16 in.)

This engine gave the following results under the three conditions of working outlined above :

—		I	II	III
Speed, km. (*miles*) per hour		20 (12.4)	30 (18.6)	40 (24.8)
Indicated f.-ch. (*horse power*)		333 (328)	620 (612)	970 (957)
Indicated tractive effort in kgr. (*in lb.*)	F =	4 500 (9 920)	5 600 (12 346)	6 500 (14 330)
Draw bar pull, in kgr. (*in lb.*) :				
on the level		3 600 (7 937)	4 650 (10 250)	5 550 (12 235)
on rising gradient of 1 in 100		2 700 (5 952)	3 750 (8 267)	4 600 (10 140)
Weight of train, in metric (in English) tons :				
on the level		1 560 (1 525)	1 660 (1 634)	1 580 (1 555)
on the gradient		220 (217)	290 (285)	340 (335)
Hourly steam consumption of the cylinders D_m : kgr /h. (*lb.* per hour)		3 000 (6 614)	5 300 (11 685)	7 700 (16 976)
Hourly steam consumption, kgr. per m² (*lb.* per sq. foot) of heating surface H.... $Z_m = \frac{D_m}{H}$		18 (3 69)	32 (6.55)	46 (9.42)

(1) Calculated on the side exposed to the gases.

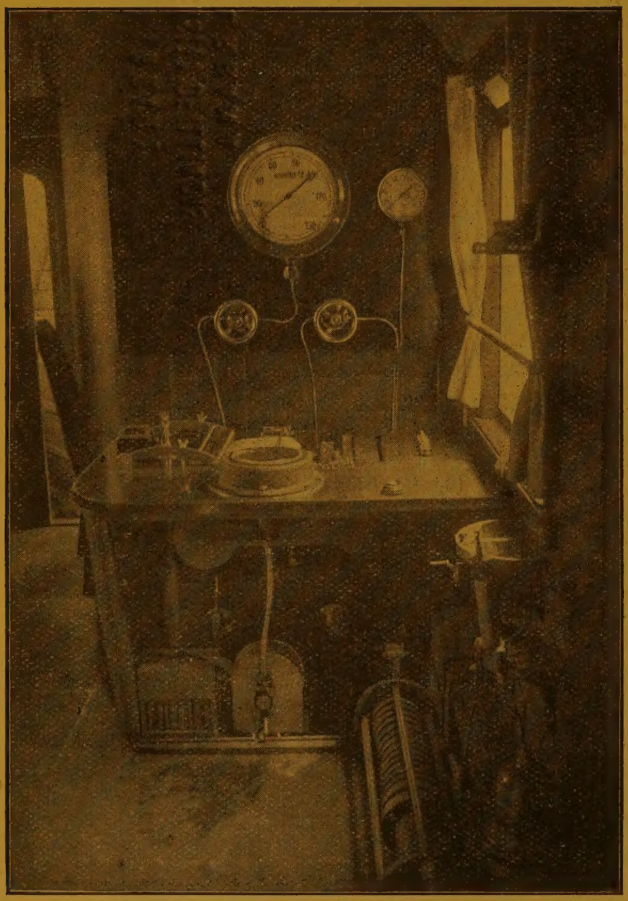


Fig. 3. —View of the dynamometer table.

Fig. 4. — Laboratory for chemical analyses.

Each of these three last figures represents a method of working the engine corresponding, for the arrangement under test, to the given regulator opening, the quality of the coal and the method of firing used, and the possibility of burning a certain quantity of coal which, under these same conditions, produces a quantity of steam D which should be at least equal to the quantity required D_m. This quantity of coal will vary with the arrangements used.

It follows that the first calculation to be made is the ratio $\frac{D}{B}$ between the hourly quantities of water evaporated D and the quantity of coal burnt B, or if desired : the ratio between the hourly rates $Z = \frac{D}{H}$ of water evaporated per square metre of

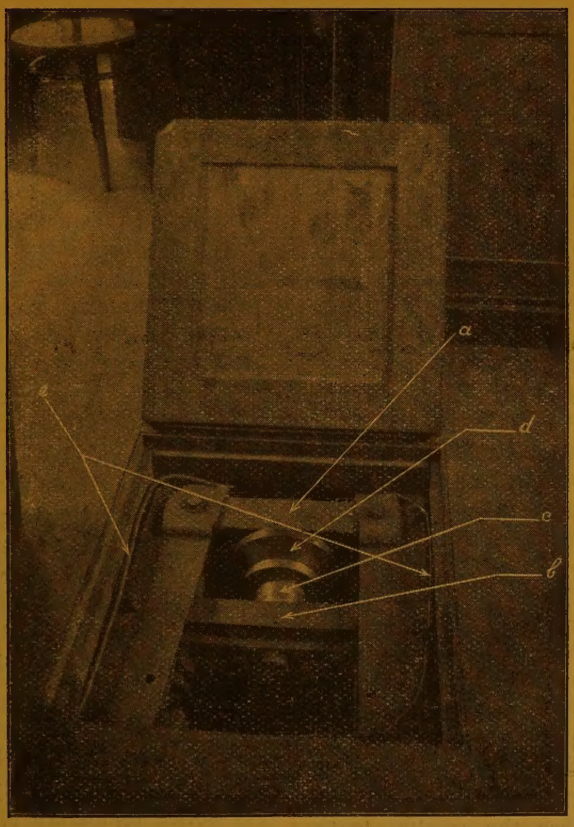


Fig. 5.

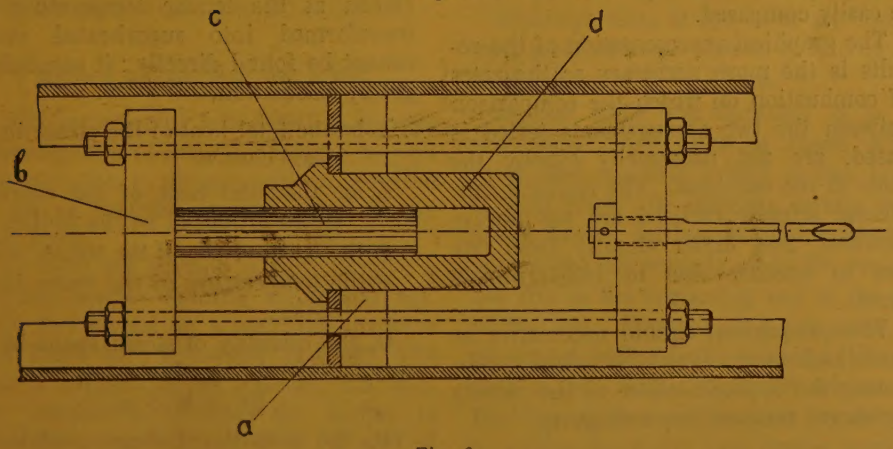


Fig. 6.

Figs. 5 and 6. — Hydraulic traction dynamometer (fitted under the floor of the car).

a = Detail fastened to the frame;
b = Detail secured to the drawbar hook acting on *c*;
c = Piston of cylinder *d*;
d = Cylinder;
e = Pipes to the indicating and recording instruments.

heating surface and $Y = \frac{B}{R}$ of coal burnt per square metre of grate area (rate of combustion).

We wish to call attention to the distinction we make between the consumption of steam by the engine for the work it has to do D_m (or Z_m) and the quantity of steam produced by the boiler D (or Z) because these quantities are not necessarily equal.

If there is a difference, it does not mean, unless too great, that the arrangement tested is not good enough, but only that some boiler detail such as the blast pipe for example, requires to be altered to get the desired equality. In the calculation it is necessary, however, to take into account the difference which can exist between D_m and D.

When the law of variation of D in terms of B : $D = \varphi(B)$, or wich comes to the same thing : $Z = f(Y)$ has been arrived at, and especially when it has been given in the form of a curve, the results obtained with the different arrangements tested can be easily compared.

The graphical representation of the results is the more necessary as the rates of combustion on which the comparison between the two arrangements tested is based, are not necessarily exactly the same in the two tests. The running conditions actually realised are not always identical, they differ slightly from one test to another due to indeterminate causes.

The comparison should necessarily be made as between exactly identical conditions : the representation of the results by curves removes any ambiguity.

Determination of the production of steam.

In order to ascertain the principal boiler factor $D = \varphi(B)$, the hourly quantity of coal burnt and the hourly quantity of water evaporated *by this coal* must be measured during the test. Now if we know well the quantity of coal burnt between the beginning and the end of the test, that is to say *between opening and closing the regulator*, the quantity of water evaporated by *this* coal is not so well known.

As a general rule the quantity of steam D_m used by the locomotive during the test is greater than the quantity D of the water evaporated by the coal burnt.

The quantity of steam D_m is the sum of the quantities of water M which disappear from the tender and m from the boiler, in which the level is lower at the end of the test than at its beginning, less the ultimate losses of the boiler Σd.

The coal burnt has supplied the heat units needed to evaporate the quantity of water M taken at the temperature in the tender and the quantity m of water taken at boiler temperature. The quantity of water D really evaporated by the boiler (taken at the tender temperature and transformed into superheated steam) cannot be found directly : it can only be got by calculation.

If λ_1 be the total heat of the steam in the steam chests,

λ_K be the total heat of the saturated steam produced by the boiler,

$t°$ the temperature of the tender water,

$q°$ the temperature of the water in the boiler,

D_K the quantity of steam spent by the boiler during the test,

$$D^K = M + m$$

D_m the quantity of steam used by the cylinders which is less than the former owing to blower, safety valves, etc. losses,

$$D_m = D_K - \Sigma d = M + m - \Sigma d,$$

M the quantity of water supplied from the tender,
m the quantity of water supplied by the boiler,
we get the equation

$$D(\lambda_s - t) = D_K \lambda_K - (M.t + m.q) + D_m (\lambda_s - \lambda_K)$$

Heat supplied to transform into saturated steam $D_K = M + m$ kgr. of water of which M is taken at $t°$ and m at $q°$.

Heat supplied to superheat the steam D_m used by the cylinders.

which shows that the heat units supplied by the boiler equal the heat units contained in the steam used less the heat units introduced by the tender water ($M.t$) and those ($m.q$) borrowed from the reserve water.

From this we get

$$D = \frac{D_K.\lambda_K + D_m(\lambda_s - \lambda_K) - (M\,t + m.q)}{\lambda_s - t}.$$

This formula shows the quantities that have to be measured during the trial so as to be able to calculate D.

Method of carrying out a test.

Without entering into detail as regards those matters of little importance we will call attention to the precautions required to get an accurate measurement of the coal burnt.

In itself the method is very simple : a tipping hopper holding about 100 kgr. (220 lb.) placed on a weighing machine and fitted with a counter is used. The coal is weighed by the 100 kgr. (220 lb.), the number n of times the hopper is tipped is recorded, and if at the end of the test b kgr. coal remains, the quantity used

$$B = 100\ n - b.$$

Much more important than the method of weighing the coal loaded on to the tenders is the calculation of the coal *really burnt during the trial.* The weight of coal burning in the firebox as well as the temperature of the arch at the beginning of the trial is generally estimated by the eye. As regards this, the American tests are not in any way more accurate. All that can be done is to reduce the relative error which follows by increasing the duration of the test.

Although tests of one hour are considered acceptable the normal period of test at the plant is three hours.

In our tests, the duration is as given above : one hour at heavy firing rates, and one and a half to two hours at light rates. In addition, certain rules are followed, having as their object to reduce the uncertainty as to the state of the fire at the beginning and at the end of the test. First of all a test must not be started with a badly burning fire, nor with a dull arch. With this object the first ten or twenty kilometres are devoted to getting the boiler into proper working order, care being given to having at the end of this distance a normal water level and the working pressure of the boiler.

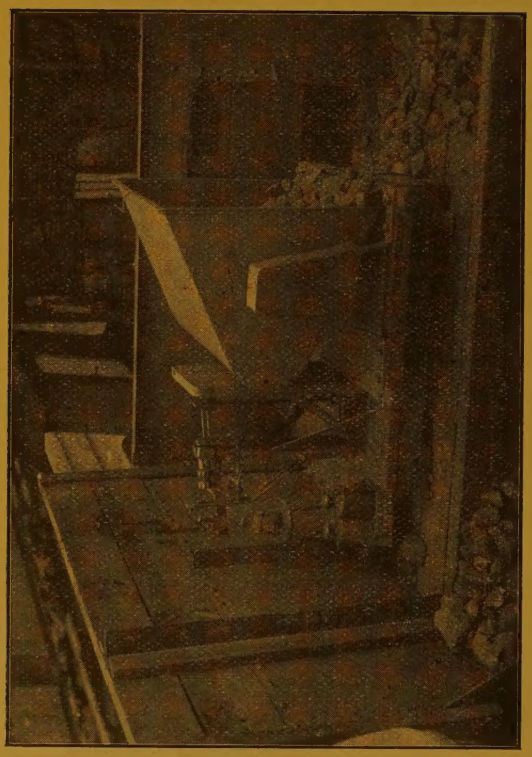


Fig. 7. — Equipment for measuring the coal.

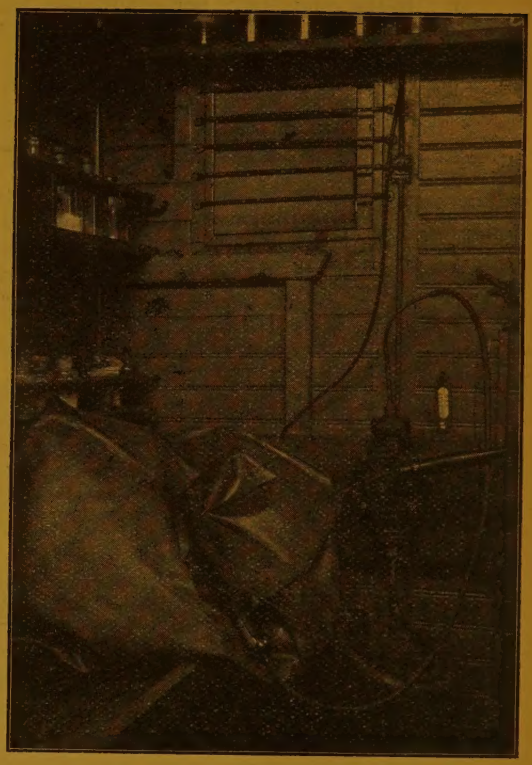


Fig. 8. — Bag in which to collect the gases.

These conditions govern the length of the preliminary run.

At the moment of beginning the trial there should only be a thin layer of coal over the grate, in fact only enough just to cover it. The first large quantity of coal is then fired so that on opening the regulator a bright fire can be got and any drop of pressure at that moment avoided. Any such drop would show that insufficient lighting up coal has been used.

In order to avoid the disturbing effect of heavy exhausts, the rule is not to open the regulator except when through the use of the « regulator » engine the train is running at the speed selected for the test. At the same time the cut-off is set to the selected figure.

This method which is only possible with a « regulator » engine, reduces the time required to get the test engine up to the proper speed and avoids any slipping which might upset the state of the fire.

When the first large quantity of coal fired is partly burnt, which coal should not only help to build up the fire but also to supply the additional heat needed to make good the great consumption of steam during the speed regulating period,

the period then starts during which the fireman takes care by firing at regular intervals to maintain the pressure at the working value and to keep a certain thichness of fuel on the grate. When approaching the end of the run, before shutting the regulator, the quantities of coal fired are steadily lessened so as to let the fire burn itself through and thereby reduce the thickness of fuel on the grate.

The moment selected for closing the regulator is that at which, on stopping the firing, the pressure gauge needle shows a tendency to fall. If at the moment of closing, the pressure rises very quickly until the safety valves lift, or if it is necessary to feed much water into the boiler and thereby raise the water level in the gauge glasses, this shows that the regulator has been shut too soon and before the coal has been well burnt. In this case, the measurement of the coal used gives too high a figure, part of the coal not having been used to produce work.

If, contrariwise, after shuting the regulator, the pressure does not remain steady, this means that the regulator has been shut too late, and that part of the work has been done not at the expense of the coal fired but of the reserve of water in the boiler; the measurement of the coal gives too low a figure.

The result of all this is that, to avoid errors in estimating the state of the fire at the beginning and at the end of the test, the moment selected for closing the regulator must be chosen with judgment. This is readily done after some practice. It is better to stop firing sooner and close the regulator rather than to take care to endeavour to make this operation coincide with arriving at a station : it is even better in certain cases to stop between stations to take the quantities rather than to go on firing too long and thereby run the risk of having to close the regulator too soon in the event of having to stop at a station.

Another special feature of our method which differs from the ordinary methods may be mentioned. In these latter, to avoid any calibration of the boiler the level of the water is brought up to its original level before measuring the water taken from the tender. We do not follow this custom because, as this operation is done after the regulator is shut, it introduces an error equal to the latent heat of evaporation of the water so introduced. In working in this way, account is certainly taken of the quantity of coal required to raise this water to the temperature of the boiler water, but the water evaporated during the trial, which has also had to be replaced, has required for its evaporation a supplementary supply of coal which is not accounted for. From this head, errors creep in to the determination of the ratio of D to B. For this reason also, our method excludes from the measurement of the coal the part required to build up the fire and for raising the water level in the boiler.

In this way D can be distinguished from D_m, and D and B can be more accurately estimated. Besides the calculation of the quantity of water evaporated per square metre of heating surface Z in terms of the rate of combustion Y, we also calculate the heat efficiency of the boiler η.

This efficiency η is found from the equation

$$B.K.\eta = D(\lambda_s - t)$$

which shows that the heat units given by the combustion of B kgr. of coal of a ca-

lorific value K with a boiler thermal efficiency of η have evaporated D kgr. of water from a temperature of $t°$ and converted it into steam of a total heat λ_s. The second term of this equation is calculated in the way already shown.

From this equation we get

$$\eta = \frac{D\,(\lambda_s - t)}{B.K}$$

which is the expression for the efficiency and can only be found by a trial.

After having found η we get

$$\frac{D}{B} = \frac{\eta.K}{\lambda_s - t}$$

which gives the evaporative power of the coal in superheated steam of total heat λ_s.

We sometimes ascertain, as a means of comparison in the case in which the superheat temperature T_s differs from one trial to another, the volume of steam V_s in cubic metres at the superheat temperature T_s in the steam chest.

From this calculation we get the comparative figures :

$\frac{V_s}{B}$, volume of steam at $T_s°$ per kgr. of coal burnt,

$\frac{V_s}{H}$, volume of steam at $T_s°$ per square metre of heating surface, analogous to the figures :

$\frac{D}{B}$, weight of water evaporated per kgr. of coal,

$\frac{D}{H}$, weight of water evaporated hourly per square metre of heating surface.

These figures $\frac{V_s}{B}$, $\frac{V_s}{H}$ are of interest for the following reasons : although we are only considering boiler tests, it may be of value to compare from one test to the other, what part of the heat units in the coal is transformed into work in the cylinders; now, at equal pressure the power is very nearly proportional to the volume of steam produced V_s. From one test to the next, a lower rate of evaporation may be compensated for by a higher superheat; V_s takes into account at the same time evaporation and superheat.

Preparation of the heat balance sheet.

All thorough boiler tests should include the drawing up of the balance sheet showing the losses of heat units.

If a kilogramme of coal gives K calories and the boiler efficiency be η, the number of calories used is $K\eta$, the number of calories lost is $K(1 - \eta)$.

The following are the causes of these losses :

1. Evaporation of the water in the coal. . . . . Q_0 cal.
2. Losses in soot, sparks, unburnt coal in the ashes, clinker, cinders, losses of coal through the fire bars. Q_1 cal.
3. Losses through incomplete combustion and the formation of carbon monoxyde. Q_2 cal.
4. Heat units taken away in the combustion gases . . . . Q_3 cal.
5. Losses through radiation . . Q_4 cal.

Analyses of the gases.

As we all know, the calculation of these losses is done by analysing the products of combustion and those losses which should be attributed to inderminate causes are ascertained by making the difference between the total of the losses, total known, and the sum of the calculated losses.

In the case of locomotives, one cannot hope to ascertain the heat units taken away in the cinders : one endeavours, however, to estimate the radiation losses. This is the method of drawing up the heat balance sheet given by Lawford H. Fry in his book *The locomotive boiler* (Simmons Boardman Publishing Company, 30, Church Street, New York, or 34, Victoria Street, London).

If we estimate, like Lawford H. Fry, that the radiation loss is about 5 % of the heat used :

$$Q^4 = 0.05\ K\eta$$

and if X be the part of the quantity C of coal given by the analysis of the fuel which, for the reason given above was not burnt, the following well known equations may be written :

$$Q_0 = 600\,(qH + W).$$

$$Q_1 = 8\,100\,X.$$

$$Q_2 = 5\,680\,\frac{CO}{CO^2 + CO}\,(C - X) = \alpha\,(C - X).$$

$$Q_3 = 1\,867\,\frac{C - X}{CO^2 + CO}\,[0.42\,CO^2 + 0.31\,(100 - CO^2)]\,(T - t) +$$

$$+ 1.24\,(qH + W)\,0.47(T - t) = \beta\,(C - X) + \gamma.$$

$$Q_4 = 0.05\ K\eta.$$

Since $\Sigma Q + K\eta = K$, we get

$$X = \frac{K - K\eta - (\gamma + Q_0 + Q_4) - (\alpha + \beta)\,C}{8\,100 - (\alpha + \beta)}.$$

After calculating X we find the values of all the losses Q and the value as a per cent :

$$\eta_i = \frac{Q_i}{K}\,100$$

after which the balance can be drawn up.

This method of calculating the losses cannot be absolutely accurate. It is however sufficiently so for comparative purposes and, moreover, is very convenient in the case of tests of locomotives, as it completely eliminates the need for collecting and analysing the residues of combustion, a duty never very thoroughly carried out on the railways, at least so far as we know.

Weighing the residues has in practice quite another utility and serves only to give an idea of the length of the run that can be made without having to clean the fire or the smoke box.

The one and only test that must be made in order to draw up the heat balance sheet consists in analysing the combustion gases by the Orsat instrument. In order to use it on locomotives, all that is necessary is to follow a few instructions which easily work in with our method of testing.

In order that the gas taken may be representative and to avoid it being taken either when firing or when the coal is nearly fully burnt, in short in order to obtain an average sample, samples are taken continuously and the samples are collected in a rubber vessel of about 1 m^3 (35 cubic feet) capacity.

A supplementary precaution to assure constant results from the tests consists of only using coal from a reserve supply kept in covered wagons and protected from atmospheric conditions.

The methods described above have been carefully followed by us since 1927. They have enabled us to raise boiler tests to a very high level.

Sometimes we have found it sufficient to determine three points of a curve to draw it with sufficient accuracy for the points found by counter-tests to fall quite close to it.

III. — Application to the test of a smoke consuming device.

We will now show how the general methods we have just explained have been applied to the particular case of the investigation of a smoke consuming device.

The « Langer Fuel Saving Corporation of America » submitted to us for trial a smoke consuming device known at that time as the « Langer », subsequently changed to « Pyram » in order to prevent any confusion with the old Langer equipments. The Pyram tested, although it emerged from the Langer, is a completely rearranged and improved device.

The Company put forward the device as being, at once, a smoke consumer, an apparatus for improving the boiler efficiency, and as a spark arrester. These were the points which had to be proved and at the same time the advantages had to be given numerical values.

The Company in question placed at our disposal, early in 1928, four sets of equipment. Three of these were fitted to locomotives so as to be tested in ordinary working; the fourth was fitted to locomotive No. T 12, the leading dimensions of which have been given, in order to be tested scientifically following the method described above. This locomotive was particularly suitable for several reasons : as it had already been used for a number of tests it was already fitted with all necessary devices and the results of further trials could be more readily and more exactly compared with the previous figures.

As regards a description of the device and its method of working, we will limit ourselves to giving the following summary of the notices published by the makers, to which notices readers wishing more detailed information are referred.

Description of the Pyram apparatus.

The apparatus consists of :

— a special firebox door;
— a nozzle in the firebox;
— a three-way valve;
— an automatic valve which supplies steam to the nozzle in the firebox or to the locomotive blower, or to both at the same time;
— the Réglair, a draught regulating device;
— the steam pipes necessary for interconnecting the above fittings and the boiler;

Figure 9 shows the general arrangement. The work of the apparatus is quite automatic, except as regards that of the firebox door, which is semi-automatic.

Firebox door.

The firebox door carries a conduit leading the outer air to the firebox, heating it on its way. When the door is opened a flap automatically opens this conduit, and it remains open, when the door is shut as long as additional air is required

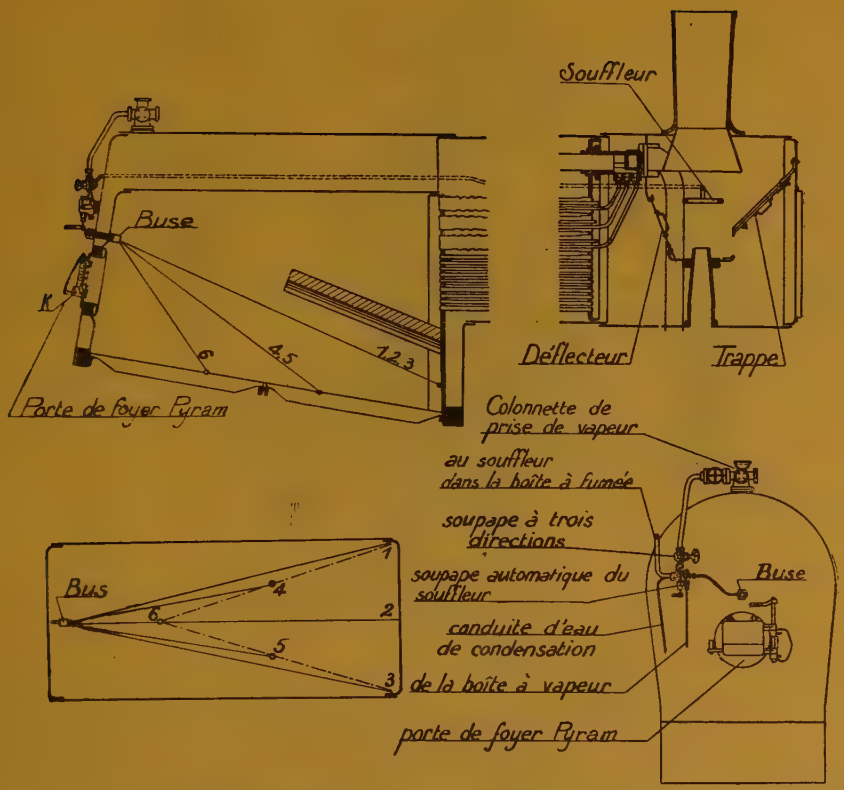


Fig. 9. — General layout of the Pyram equipment

Explanation of French terms: Au souffleur dans la boite à fumée = To the blower in the smokebox. — Buse = Nozzle. — Colonnette de prise de vapeur = Column from which steam is taken. — Conduite d'eau de condensation = Condensed water pipe. — Déflecteur = Deflector. — De la boite à vapeur = From the steam chest. — Porte de foyer Pyram = Pyram fire hole door. — Souffleur = Blower. — Soupape à trois directions = Three-way cock. — Soupape automatique du souffleur = Automatic valve of the blower. — Trappe = Trap.

for the combustion of the hydrocarbons; the fireman closes the flap when he thinks additional air is no longer needed.

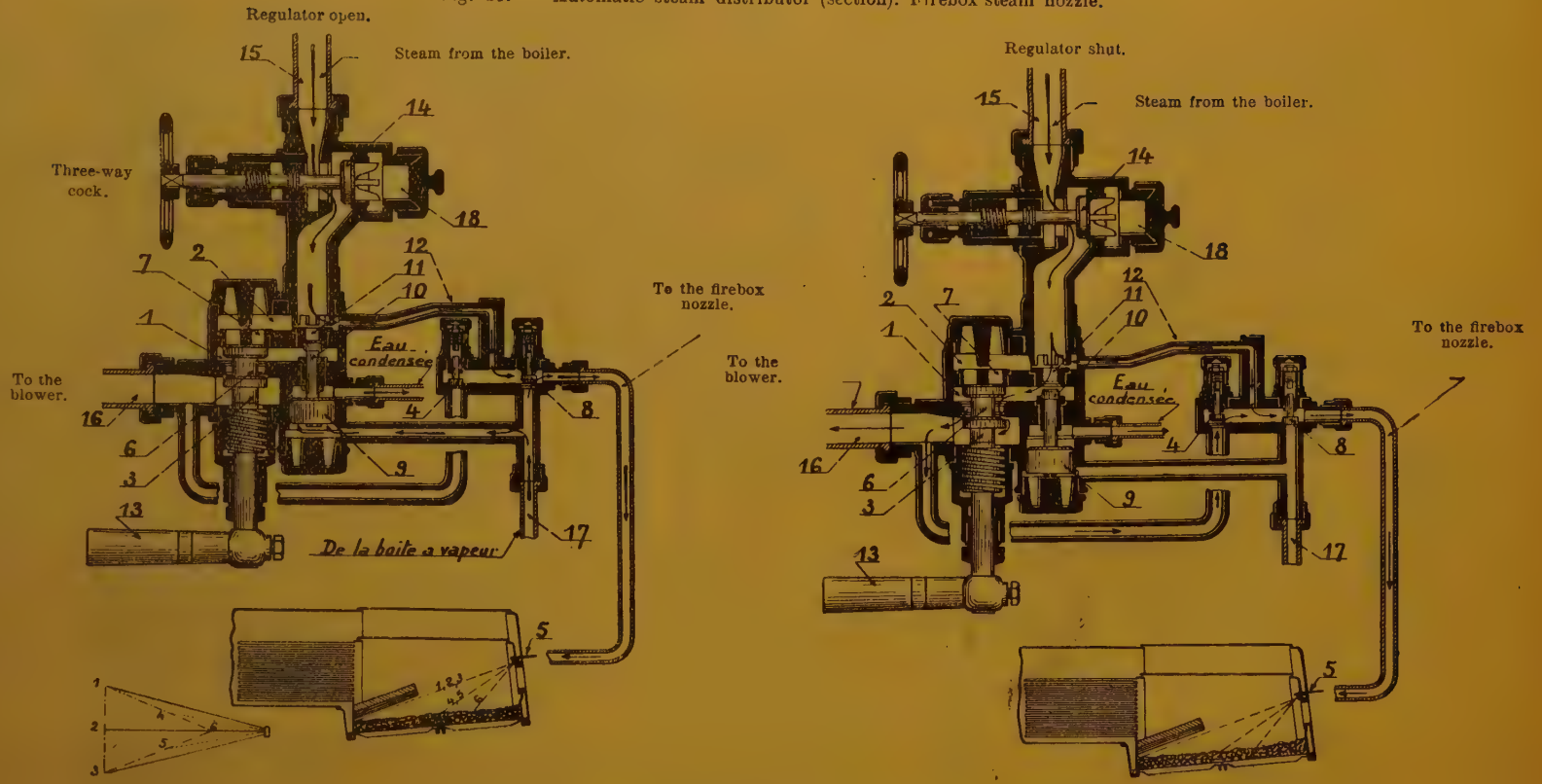
Firebox nozzle.

Above the fire hole door in the firebox, a nozzle made of special heat-resisting steel is fitted, which is fed through a steam pipe originating in the automatic valve and supplies diverging steam jets forming a pyramid, the base of which is represented by the layer of coal.

Three-way valve.

A three-way valve supplies steam from the boiler to the automatic valve, or for lighting up. It can also be used as a by-pass for the automatic valve.

Fig. 10. — Automatic steam distributor (section). Firebox steam nozzle.



The handle of the automatic distributor is shown in the running position.

1. Middle chamber.
2. Upper chamber.
3. Lower valve, hand operation.
4. Retaining valve.
5. Jet and supply pipe.
6. Upper valve, hand operation.
7. Upper valve seat.
8. Retaining valve.
9. Differential piston.
10. Valve attached to piston.
11. Seat of valve 10.
12. Cooling pipe.
13. Hand operating lever.
14. Three-way cock.
15. Steam pipe.
16. Connection to the smokebox blower.
17. Connection to the steam chest.
18. Fitting for lighting up.

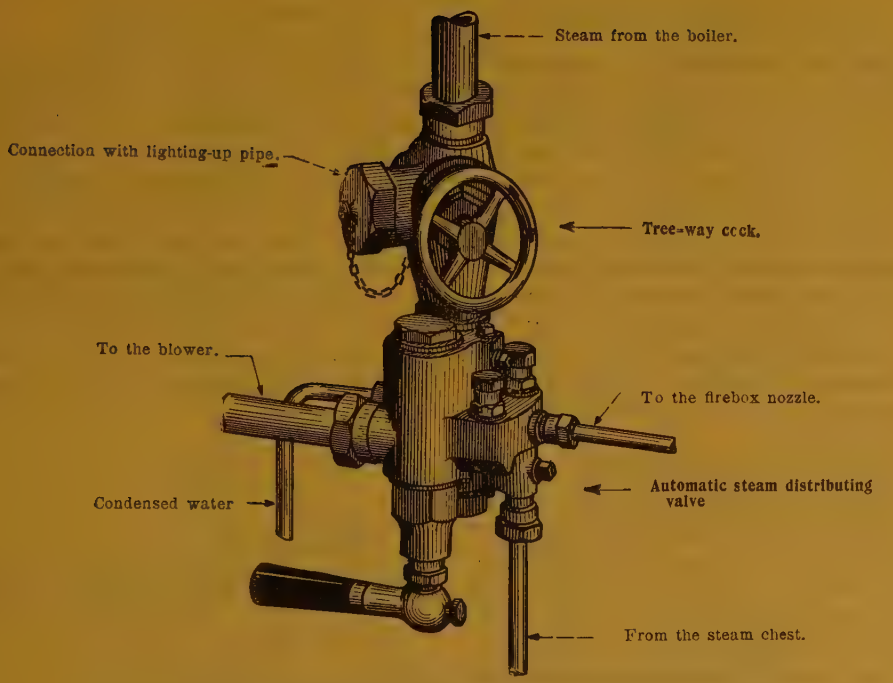


Fig. 10 (*continued*). — Automatic steam distributor and three-way valve. General view.

Automatic valve.

The automatic valve takes steam either from the boiler through the three-way cock, or from the steam chest : it supplies steam either to the firebox nozzle or to the blower.

The connections to this valve are as shown in figure 11.

This valve has an operating handle which the fireman can set in four main positions, according to the rate of combustion desired (fig. 12).

Position I : Shut.
— II : Running.
— III : Forced working.
— IV : Shut.

The handle can and should, according to need, be placed in any intermediate position : when running it is generally between positions II and III.

The path of the steam for the different positions of the handle with the regulator both open and shut, is shown diagrammatically in figure 13.

Réglair.

The *Réglair* consists of two plates dividing the smokebox into three chambers communicating with one another by two openings, the dimensions of which are calculated on the large side so as to offer less resistance to the draught than the grate.

Working of the Pyram.

The air required for the combustion of the hydrocarbons liberated is introduced through the door immediately after firing. This air is directled upon and left in contact with the fuel on the grate by the jet of steam. This cone shaped jet which forms, as it were, a gazeous extension of the arch, mixes the gases with the air and forces them to go round the arch, in this way increasing the length of the distance they travel; their complete combustion is assured thereby and the giving up of the heat contained in them is facilitated.

Thanks to the automatic valve, the firebox nozzle, when the regulator is opened, is supplied with steam from the steam chests the more abundantly the higher the pressure in the steam chests and therefore as the regulator is wider open, that is to say generally by as much more as more work is required of the engine.

As soon as the regulator is shut, the valve automatically keeps the smokebox blower and the firebox jet at work by supplying steam from the boiler. In this way a moderate fire is kept going in such a way as to prevent any blow back of the flames and the formation of clinker.

The Réglair by cutting out the violent effect on the fire of the beats of the exhaust, prevents the production of cinders.

The whole of the details of the Pyram equipment contribute to the same objective : elimination of smoke, suppression of cinders, and the improvement of the boiler efficiency. A full description of them cannot be given here; we will limit ourselves to describing the methodical tests which enabled us to check the claims of the makers and to give the numerical values.

Programme of the tests.

In order to be able to find the part due to each constituent of the Pyram equipment in bettering the efficiency of the boiler, we decided first of all to make tests without the Réglair, retaining on the engine the usual smokebox fittings, then to fit the Réglair and make tests with it alone and with the steam cone; finally to make tests with the whole equipment.

The results are shown in the form of diagrams, all drawn with the hourly rate of combustion per square metre of grate area as abscissæ.

$$Y = \frac{B}{R}.$$

1. On some of them the ordinates represent the hourly rate of production of steam per square metre of heating surface $Z = \frac{D}{H}$ as well as the quantity $\frac{D}{B}$ of water evaporated per kilogramme of coal.

2. On others the ordinates represent the value of the efficiency in percent, and also, as a percentage, the unavoidable losses due to the different causes which make this efficiency less than 100 %.

In this way we get the curves η_0, η_1, η_2, η_3, η.

The distances between the 100 °/₀ efficiency line and curve η_0 correspond to the losses due to the water contained in the coal.

The distances between the line η_0 and η_1, represent the losses through unburnt fuel (sparks, cinders, etc.),

The distances between the lines η_1 and η_2 represent the losses due to incomplete combustion (formation of CO, etc.).

The distances between the lines η_2 and η_3 represent the losses due to the hot gases passing out through the chimney.

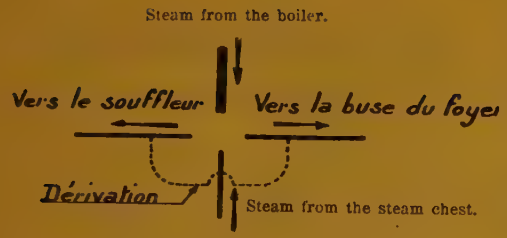


Fig. 11. — Connections of the automatic valve.

Explanation of French terms:
Dérivation = By-pass. Vers la buse du foyer = To the firebox nozzle. — Vers le souffleur = To the blower.

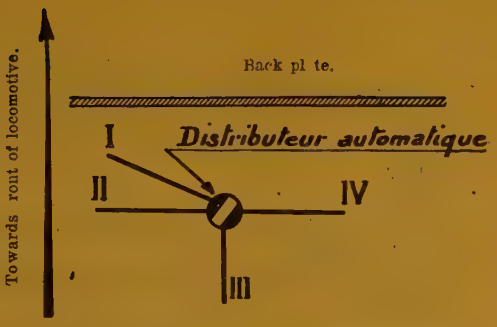


Fig. 12. — Different positions of the handle of the automatic valve.

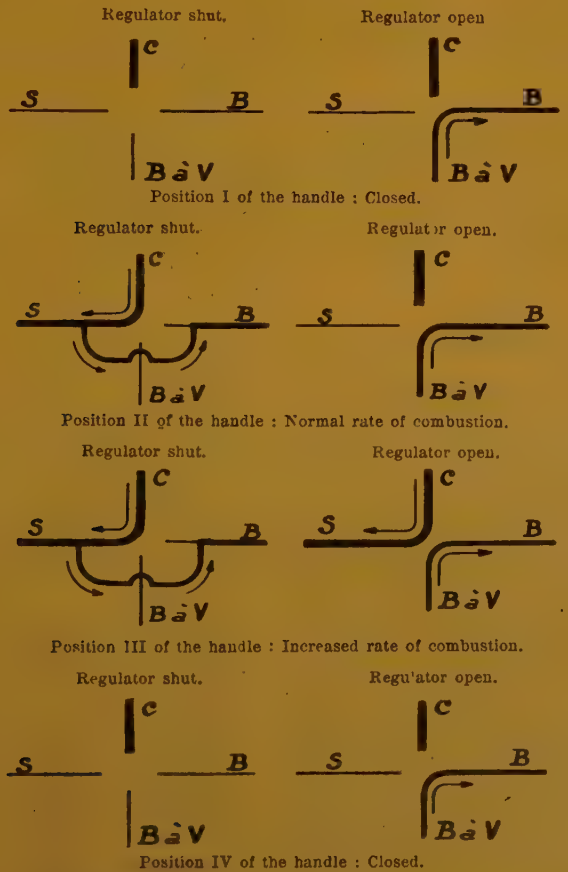


Fig. 13. — Diagram of the working of the automatic valve with the handle in the different positions and with the regulator shut or open.

The distances between the lines η_3 and η represent the losses through radiation.

The curve η represents the output of the boiler.

3. Other diagrams in addition represent separately :

the temperature of the superheated steam T_s;

the temperature of the gases in the chimney T_α;

the excess air *m;*

the proportion of CO^2;

the proportion of free oxygen O;

the proportion of CO.

On most of the diagrams fine lines represent the results obtained with the normal engine and heavier lines relate to the tests with the Pyram equipment (or, according to the case, with part only of this equipment).

Tests with Renard coal.

A first series of tests were made using Renard mine coal from the Dombrowa fields; this is the coal generally used for making tests and which is used as the basis of comparison.

The results are shown in the diagrams, figures 14 and 15. The improvement obtained by working the firebox jet is clearly shown and it increases with the rate of combustion Y.

For a rate of combustion of 300 kgr. (61.5 lb. per sq. foot) per hour, which approaches the maximum in ordinary working for the test locomotive, the ratio of the quantities of water evaporated per square metre of heating surface with the whole Pyram and without the Pyram, Z is

$$\frac{42.3}{40.1} = 1.055;$$

the ratio $\frac{D}{B}$ of the evaporative power of the coal is $\frac{6.02}{5.72} = 1.05$.

When using the steam cone alone, this figures are :

$$\text{For } Z, \quad \frac{42.7}{40.1} = 1.065.$$

$$\text{For } \frac{D}{B}, \quad \frac{6.06}{5.72} = 1.06.$$

The difference between the figures obtained represents the effect of the Réglair.

We consider the accuracy of our tests is within about 2 %.

From the above figures we may therefore conclude that the Pyram gives a saving of between 4 and 8 %, or say 6 % on the average, and that the part of this due to the Réglair is uncertain. We think the principal object of this part of the apparatus is to prevent the carrying away of sparks and cinders.

On the diagram of figures 16 and 17 which show in terms of Y the losses of heat units calculated by analysis of the combustion gases as shown in the preceding paragraph we see that almost the whole improvement in the efficiency is due to the combustion of the carbon monoxide and that this result is due the firebox jet.

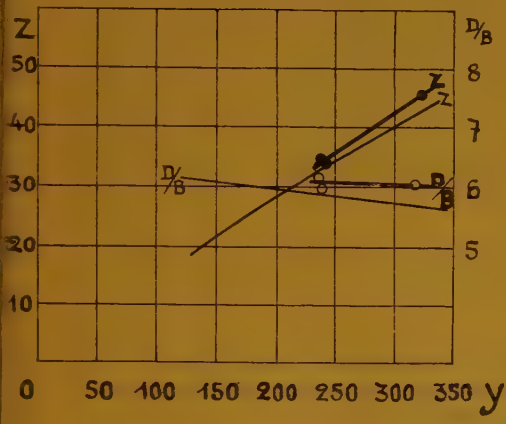
The other losses are nearly the same.

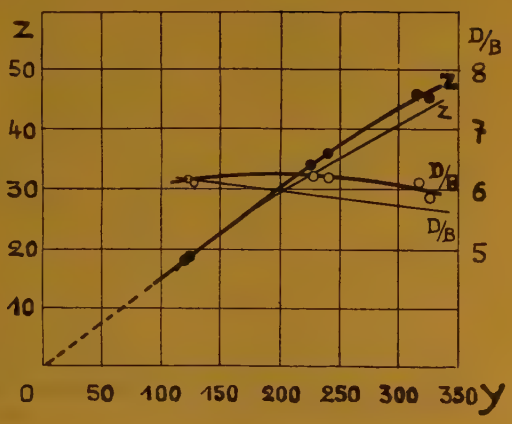
The effect of the Réglair on the carrying over the sparks and cinders can be brought out by these curves but we shall see later on how, which is better still, they can be observed directly.

To sum up : with Renard coal the use of the Pyram equipment gives a certain saving of 6 % on the average.

It must be noted however that with this high-quality coal a saving is more difficult to obtain, because under normal conditions this coal gives no smoke, no

Renard coal (Dombrowa). — Calorific value : 6 265 (11 276 B. T. U.).



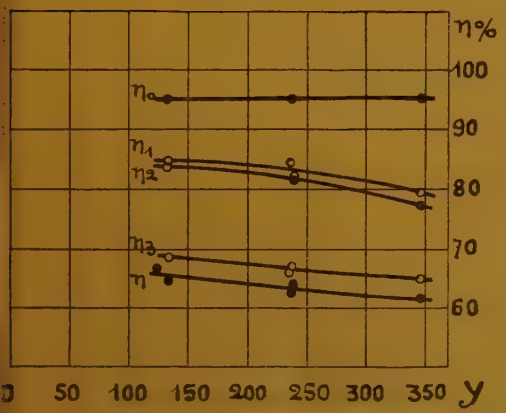


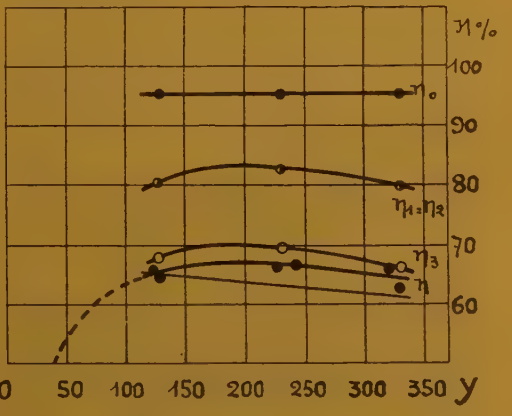
Y = Coal per hour par square metre of grate area.
Z = Steam produced per hour per square metre of grate area.
D = Steam produced hourly.
B = Coal used hourly.
———— Represents working without the Pyram.
▬▬▬▬ Represents working with the Pyram.

Fig. 14. — Equipment with Pyram complete.

Fig. 15. — Equipment with Pyram jet (without Réglair).

Renard coal (Dombrowa). — Calorific value : 6 265 (11 276 B. T. U.)





Explanation : η = Thermal efficiency.
Y = Coal burnt per hour per square metre of grate area.

Fig. 16. — Heat balance without smoke consuming device.

Fig. 17. — Heat balance with Pyram jet (without Réglair).

sparks, and little carbon monoxide (fig. 16).

We then thought of trying to improve the combustion of other coals, which produce much more smoke, by using the Pyram equipment. These were Upper Silesia coals, which we will designate A and B (this latter was used in the form of briquettes). The table below gives their analysis as well as that of the Renard coal.

Coal.	Size.	Calorific power.	Volatile matter.	C	H	O + A_z	G	Ashes + water.
	mm. (inches).	Calories (B. T. U.)	Per cent.					
Renard . . .	70 to 100 (2 3/4 to 4)	6 300 (11 340)	34	68	4	13	1	14
A	70 to 100 (2 3/4 to 4)	6 930 (12 473)	34	74	5	11	1	9
B	Briquettes.	7 020 (12 635)	37	73	5	9	1	12

These figures relate to the coal as used during the tests that is to say undried.

Heat balance sheet with B coal.

The graphs, figures 18 to 20, are for B coal for the three following cases :

1. Locomotives in ordinary working order. $Z\ \frac{D}{B}\ \eta\ \eta_1\ \eta_2$;

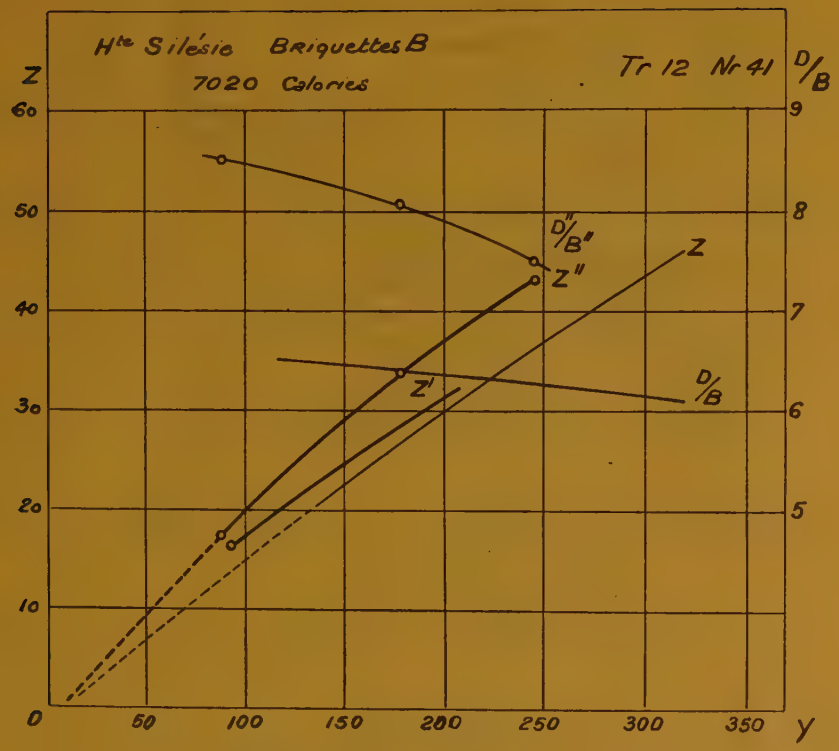
2. Réglair working alone . . . . . $Z'\ \frac{D'}{B'}\ \eta'\ \eta'_1\ \eta'_2$;

3. Pyram working as a whole. . . . . $Z''\ \frac{D''}{B''}\ \eta''\ \eta''_1\ \eta''_2$.

The graph of figure 18 shows clearly the improvement obtained. The letters without indices relate to the normal engine, those with ′ to the test of the Réglair by itself and those with ″ to the test of the whole apparatus.

The table below gives the saving obtained at equal rates of combustion.

Rate of combustion.	Réglair alone $\frac{Z'}{Z}$	Pyram complete $\frac{Z''}{Z}$
kgr. m²/h. (lb. per sq. foot per hour).		
100 (20.5)	$\frac{17.4}{15.3} = 1.14$	$\frac{19.7}{15.3} = 1.30$
150 (30.75)	$\frac{24.4}{22.7} = 1.07$	$\frac{29.0}{22.7} = 1.28$
200 (41)	$\frac{31.7}{30.0} = 1.06$	. . . . .
250 (51.25)	. . . . .	$\frac{43.8}{39.6} = 1.18$
	The saving varies between 6 and 14 %.	The saving varies between 8 and 30 %.



D/B = Evaporation figure.
Y = Quantity of coal burnt per square metre of grate area.
Z = Quantity of water vaporised per square metre of grate area.
Upper Silesia B briquettes, 7 020 cal. (12 635 B. T. U.).

Fig. 18.

The figures are obviously the same for the evaporative power of the coal $\frac{D}{B}$.

It will be observed that with this coal the action of the Réglair considered solely as a coal economiser (an accessory function) is far from negligible. It increases when the rate of combustion decreases and is responsible for half the total saving at the rate of 100 kgr./m²/h. (20.5 lb. per sq. foot per hour).

The causes of the large economies recorded are revealed by a study of the graph of losses (fig. 19).

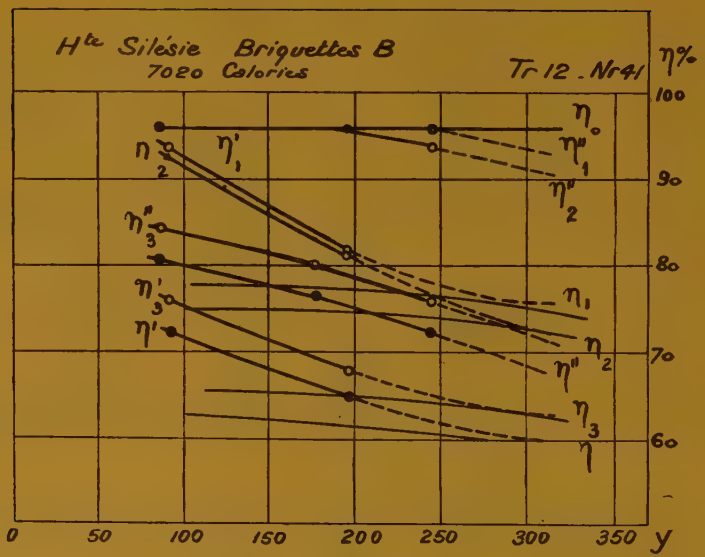
I. — *Losses through unburnt fuel.*

These losses are represented by the parts of the ordinates lying between the following efficiency curves on the diagram figures 19 and 19_1.

η_0 and η_1 for normal working;

η_0 and η'_1 for working with the Réglair;

η_0 and η''_1 for working with the whole Pyram.



Z D/B η without apparatus.
Z' D'/B' η' with Réglair alone in use.
Z'' D''/B'' η'' with complete Pyram in use.

Upper Silesia B briquettes, calorific value 7 020 (12 635 B. T. U.).

B briquettes.

Losses through unburnt fuel.

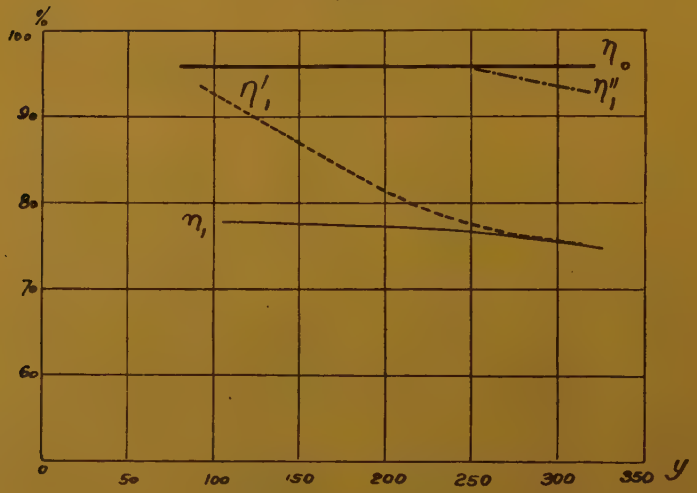


Fig. 19_1 (from diagram 19).

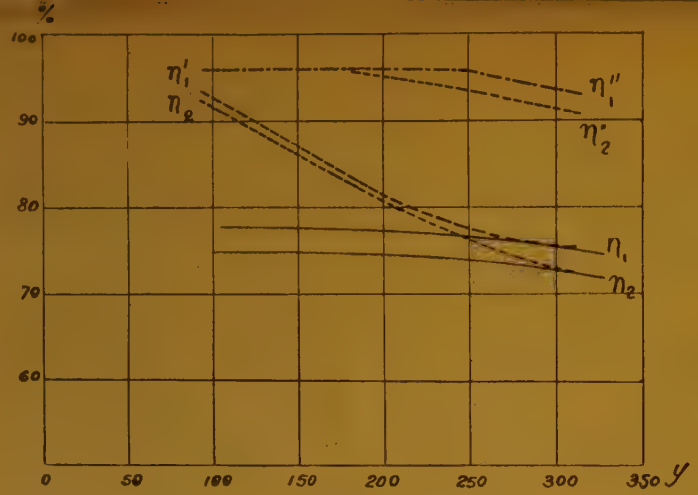


Fig. 19_2.

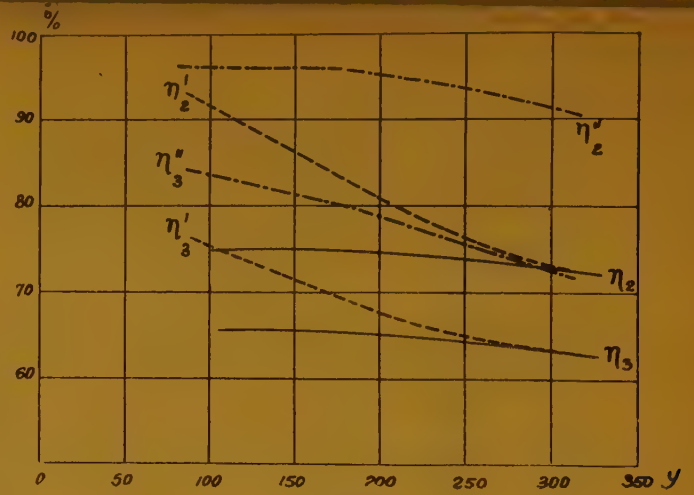


Fig. 19_3.

B briquettes.

Losses through radiation,

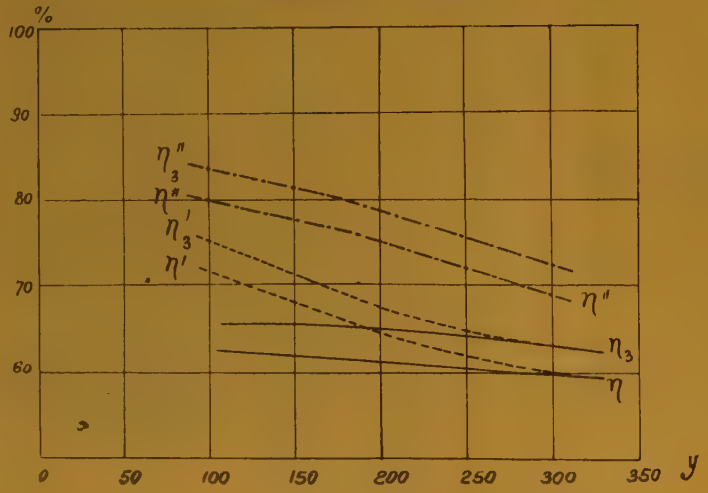


Fig. 19_4.

B briquettes.

Overall efficiency.

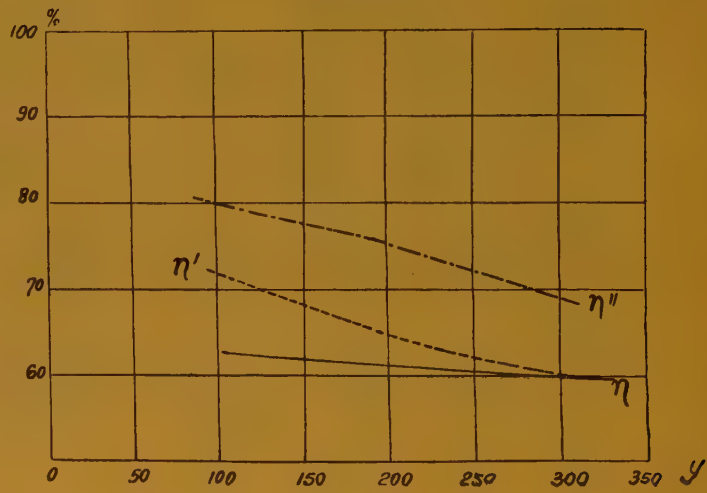


Fig. 19_5.

The diagrams figs 19_2 to 19_5 are drawn from diagram fig. 19.

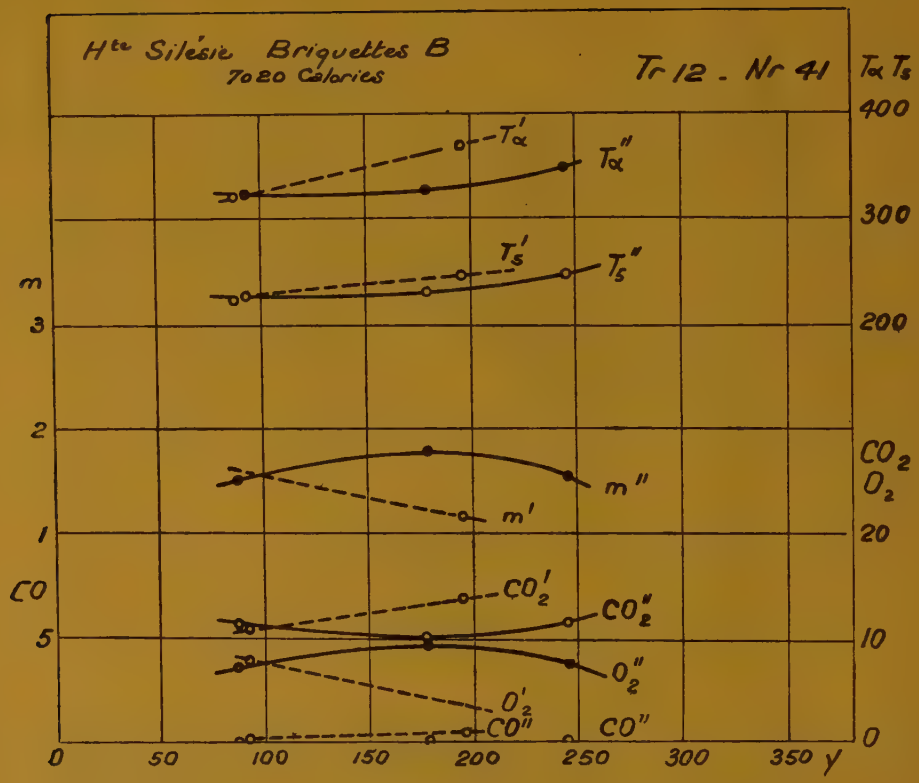


Fig. 20.

EXPLANATION : T_s = Temperature of superheated steam.
T_α = Temperature of gases in chimney.
m = Excess of combustion air.
Upper Silesia B briquettes, 7 020 cal. (12 635 B. T. U.).

These show that the effect of these fittings is to reduce the losses in a considerable proportion : at low rates of combustion through the Réglair and at high rates through the steam cone, the action of which then becomes preponderating, these two parts of the apparatus completing one another in a very happy manner and thereby improve at all rates of combustion, the efficiency in a remarkable manner.

II. — *Losses through the production of carbon monoxide.*

These losses are represented by the parts of the ordinates according to the case, between the curves η_1 and η_2, η'_1 and η'_2, and η''_1 and η''_2. These show that the Réglair by itself reduces them at low rates of combustion, and that at high rates they are still lessened by the apparatus as a whole (diagrams, figs. 19 and 19_2).

III. — *Losses through the hot gases escaping through the chimney.*

These losses are represented by the parts of the ordinates, according to the different cases, lying between curves

$$\eta_2\eta_3; \quad \eta'_2\eta'_3; \quad \eta''_2\eta''_3$$

(diagrams, figs. 19 and 19_3). These losses are increased.

This was to be expected because, when using the apparatus, the same coal gives off more heat units than when it is not used; the gases are hotter, and the boiler only absorbs incompletely the additional heat, the more so as the firebox jet leads to a greater excess of air, as the diagram of figure 20 shows.

IV. — *Losses by radiation.*

The losses are represented by the parts of the ordinates, according to the different cases lying between the curves $\eta_3\eta_1$; $\eta'_3\eta'$; $\eta''_3\eta''$ (diagrams, figs. 19 and 19_4).

As was to be expected, they are approximately equal in all cases, exactly as if calculated by the Fry method.

The result of this analysis as a whole is that the cone of steam gives results which are the better the higher the rate of combustion, which would be of benefit in the case of locomotives heavily worked. As for the Pyram apparatus as a whole it has improved to a remarkable extent the efficiency of the locomotives tested as is shown by comparing the curves of the overall efficiency of the boiler $\eta\ \eta'\ \eta''$ (diagrams, figs. 19 and 19_5).

This efficiency has risen :

from 63 to 80 % for a rate of combustion of 100 kgr. (20. 5 lb. per sq. foot);

from 60 to 69 % for a rate of combustion of 300 kgr. (61.5 lb. per sq. foot).

Heat balance sheet for A coal.

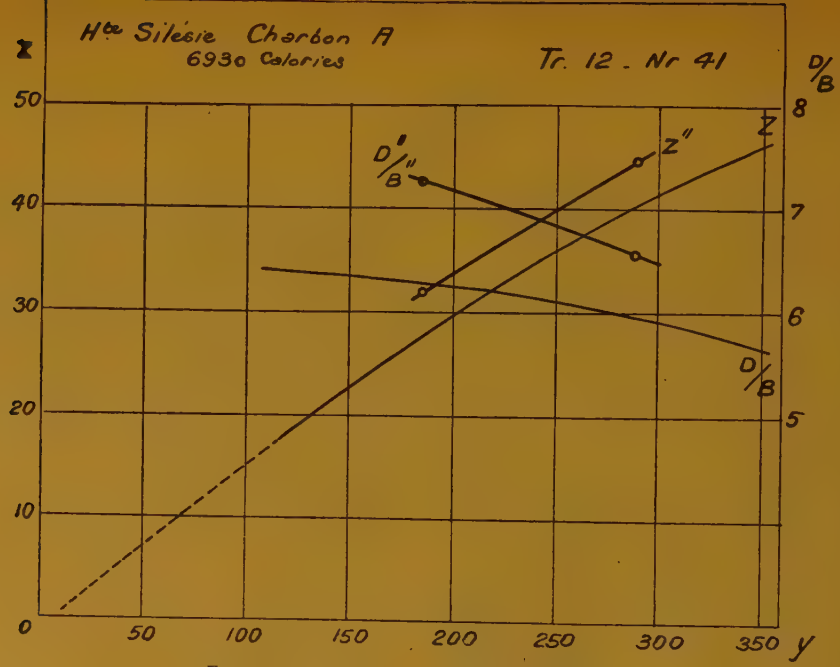
The results obtained with A coal (diagrams, figs. 21 and 22) are very alike to the preceding ones. The diagram, figure 21, shows the considerable improvement of the evaporation Z per square metre of heating surface, and of the evaporative power $\frac{D}{B}$ for the Pyram equipment in comparison with the normal engine.

They are summarised in the table below :

Rate of combustion. kgr. m²/h. (lb. per sq. foot per hour).	$\frac{Z''}{Z}$	$\frac{D''}{B''} : \frac{D}{B}$
200 (41)	$\frac{33.4}{29.5} = 1.13$	$\frac{7.16}{6.25} = 1.145$
300 (61.5)	$\frac{45.7}{41.3} = 1.105$	$\frac{6.47}{5.91} = 1.095$

or a saving of 9.5 to 14.5 %, an average of 12 %.

The reasons for this economy are to be seen in figure 22 which shows the considerable reduction in the losses through unburnt fuel, the percentage of which during trials fell from 15-18 % to 7 %; the losses through the production of CO have dropped from 4-6 % to 0-3.5 %; on the other side, the losses in the hot gases rose from 11-12 % to 15-18 %.



EXPLANATION : ——— Without equipment.
——— With equipment.

Upper Silesia A coal, 6 930 cal. (12 473 B. T. U.).

Fig. 21.

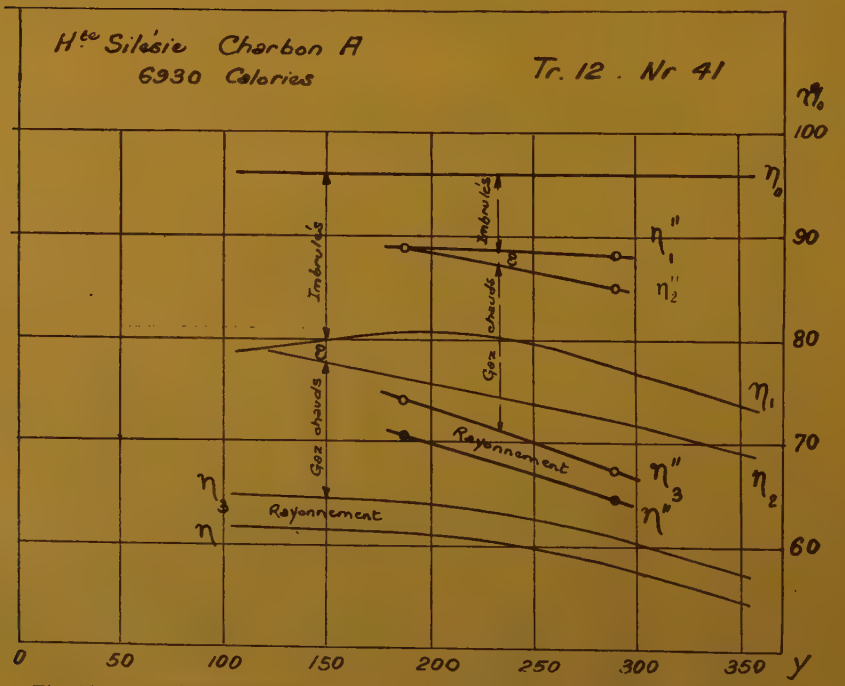


Fig. 22. — The letters marked " refer to the engine with the full Pyram equipment, those not so marked to the engine without this equipment.

Upper Silesia A coal, 6 930 cal. (12 473 B. T. U.).

Explanation of French terms

Gaz chauds = Hot gases. — Imbrûlés = Unburnt fuel. — Rayonnement = Radiation.

On the whole, however, the overall efficiency has risen from rather mediocre figures of 57.5-61 % in the case of the normal engine, to 64-70 %. The figures, which cannot be questioned, confirm the results obtained with the B coal : improved combustion, reduction in the unburnt fuel and cinders, air supplied more freely, and improved overall efficiency.

Smoke consuming effect.

It was found necessary to make direct checks on the efficiency of the apparatus as regards the smoke consuming effect, the carrying over of cinders and on the emission of sparks.

Smoke. — The Renard coal giving very little smoke, the apparatus had to be tested with A coal and B briquettes.

If the Pyram apparatus, to be truthful, does not *completely* suppress the smoke, it reduces it very decidedly.

Cinders. — The effect on the quantity of cinders carried into the smokebox can only be accurately measured after long runs at late cut-offs of as much as 45 and 50 %.

We had no opportunity for making such runs. What however was observed, was that when the apparatus was in use the weight of cinders in the smokebox was very definitely less than with it and that the cinders were much finer.

Sparks. — To observe the sparks a number of tests were made at night and it was very clearly observed that with A coal or with B briquettes and when working hard at 30 % cut-off at 40 km. (25 miles) per hour with the regulator fully open, the Pyram apparatus barely allowed to pass, and then only when actually firing, a few isolated sparks which could have been quite well counted.

We will not go into these tests because subsequently we had to repeat them in a more precise manner.

However that may be, as a result of the test we have just described and which took place in 1928, as also by the results obtained in ordinary working with the three other Pyram equipments tested at the same period, the Polish State Railways decided, in 1929, to fit the equipment on a large number of locomotives and in particular to all those being built, namely the Ty 23 (type 150) and the 0k 22 (type 230).

We took advantage of these applications to continue our scientific tests of the Pyram on these engines in order to carry still further the analysis of the phenonema.

Below are given particulars of the part of these supplementary tests which had to do with smoke consumption, a question which had not been quite cleared up.

IV. — Supplementary tests.

During the trials carried out in 1928 with a Tr 12 (type 140) engine, we were only able to form a general idea of the effect of the Pyram upon the smoke and upon the carrying over of sparks.

In 1929, we fitted a Tw 12 (type 050) engine to study the question more closely. We wished to see in particular if the absence of sparks should be ascribed to the firebox jet which makes it possible for the sparks to be completely consumed in the firebox or to the effect of the Réglair which kept them in the smokebox.

We began by making tests without the Réglair and without the spark arrester netting. The coal used came from the

Hildebrand mines (Upper Silesia). The firebox jet was sometimes used, and sometimes not. As a rule no sparks were noticed, they only began to be seen when working with 45-50 % cut off. The sparks came out as a vertical jet and went out without showing any « comet tail » effect behind the train. No great difference was noticed whether the firebox jet was working or not, there being only a slight tendency to an increase in the number of sparks when the firebox jet was not in use. In view of irregular running conditions, the forced working lasted only a short time, 15 minutes at most; the quantity of cinders collected in the smokebox gave no useful information.

The brick arch was also found the day after the trials to be defective, and this prevented any exact comparison being made with the normal engine.

No certain conclusion could be drawn from the test, and as the engine had to be withdrawn from service for reasons not connected with the tests, the latter had to be postponed.

It was not until 1930 that we succeeded in solving the sparks question when testing a Ty 23 No. 203 (type 150) engine, the standard equipment of which included the Pyram.

Practical results hab to be obtained very quickly : scientific tests were therefore not carried out but tests with certain special precautions under ordinary working conditions.

Although the results obtained as regards coal used per drawbar horse power-hour were in favour of the Pyram, there were certain contradictory results due in our opinion to the way the tests were made. For this reason they are not given here. The results obtained using a method of this sort under ordinary working conditions are never conclusive : this fact is well known and is the reason why we are not in favour of such methods.

The tests were nevertheless interesting as regards the smoke and sparks as these items do not require any special precautions.

Three similar tests were carried out with the Ty 23 No. 203 (type 150) locomotive :

one with the Réglair and the firebox jet in action;

one with the Réglair without the firebox jet;

one without the Réglair and with ordinary netting.

As regards the observations of sparks, the working selected was at night on a rising gradient of 1 in 125, 3 km. (1.86 miles) long using late cut-offs.

As regards smoke, the tests were arranged for daylight working and the results were given numerical values as mentioned above.

The coal was from the Cleofas mine in Upper Silesia.

1. *Sparks.* — Running without the Réglair and with the smoke box netting, sparks began to be emitted at 30 % cut-off. At 40 % the number was high and at 60 a stream of burning sparks were discharged full bore, were thrown high up and fell like a firework display all along the train.

With the Réglair, as a rule, no sparks were emitted under average running conditions. It was not until the cut-off exceeded 50 % that a few sparks, which went out before coming down, were observed; at 60 % cut-off the effect was more marked but there was no alteration in the general effect.

Whether the firebox jet was in use or not had no effect on the phenonema..

2. *Smoke.* — Without the firebox jet,

the smoke was not very heavy; it was clearly seen however and was readily evaluated. The emission of smoke lasted during about 45 % of the distance run and ceased on the average half a kilometre (0.3 mile) after firing.

With the firebox jet in action, difficulty was experienced in observing the beginning and the end of the emission of smoke, so little perceptible was the smoke. It was quite impossible to evaluate it and it may be considered as being practically non-existent.

Smokebox cinders. — During the whole of these tests it was not possible to measure accurately the cinders collected in the smokebox, but once again its fineness was noticed.

From these supplementary tests the real function of the Réglair is that of a very efficient spark arrester, and the smoke consuming feature is especially due to the cone of steam.

Summary and conclusion.

To sum up, our tests have shown the undoubted influence of the Pyram equipment on the improvement of the combustion.

The amount of improvement depends upon the kind of coal used. The saving of coal as compared with the coal used when the equipment is not fitted was on the *average* 6 % with Renard coal and increased to 12 % with A coal and to 16 % with B briquettes.

This improvement in the combustion is obtained at the same time as a considerable reduction, sometimes even total, in the smoke, and also in the sparks and cinders carried from the firebox.

[621. 132 5 (.493)]

The Belgian National Railway Company's "Consolidation" class 35 locomotives, [1]

by F. LEGEIN,
Chief Engineer, Rolling Stock Department of the Belgian National Railway Company.

Figs. 1 to 7, pp. 607 to 618.

The class 35 locomotive was designed with a view to replacing the class 36 *Decapod* locomotive of the Belgian State Railways, in the event of the stock of this latter type of locomotive having to be increased. The class 36 locomotive is a four-cylinder, simple expansion, superheated locomotive with a boiler pressure of 14 kgr. (199 lb. per sq. inch). Its adhesive weight equals 90.8 t. (89.4 Engl. tons) distributed over ten coupled wheels, the heaviest weight per pair being on the second coupled pair of wheels, and equals 18.8 t. (18.4 Engl. tons). The grate area is 5.1 m² (55 sq. feet). Like the class 10 [2] this type of locomotive has been modified in certain ways and as a result its power has been appreciably increased.

The superheater has been enlarged, and the blast pipe has been replaced by a double blast pipe and two chimneys.

Figure 1 is a diagram of the 36 class and gives the leading dimensions. The class 35 locomotive, four of which are now in service, was designed by Messrs J. Cockerill at Seraing, in close collaboration with the technical department of the Belgian National Railway Company (figs. 2 and 2*a*).

Particular attention was given, when designing this engine, to make it as simple as possible. The adhesive weight is equal to 93.2 t. (91.7 Engl. tons), distributed over four pairs of coupled wheels.

The boiler pressure is 14 kgr. (199 lb. per sq. inch.) and the engine has two outside, simple expansion cylinders; the frame is of the bar type. The leading truck is of the American pattern already tried out successfully on the Belgian State class 38 locomotives.

The grate area of the class 36 locomotive has been retained, and the firebox has the same depth. The diameter of the coupled wheels is also 1.450 m. (4 ft. 9 5/64 in.).

The average theoretical tractive effort $T = 0.75 \frac{pd^2l}{D}$, will equal 22 028 kgr. (48 561 lb.). The ratio $\frac{T}{A}$ of the tractive effort to the adhesive weight is therefore equal to $\frac{1}{4.23}$.

The 35 class locomotive being required

(1) Translated from the French.

(2) See *Bulletin of the Railway Congress*, August 1926 number.

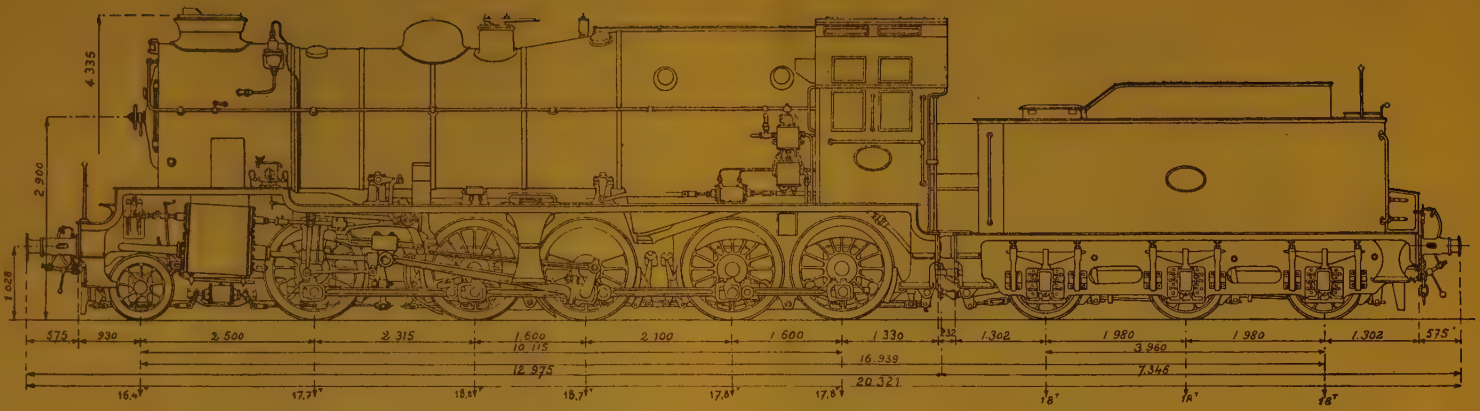


Fig. 1. — Class 36 goods locomotive, as altered.

Leading dimensions.

Number of cylinders		4
Cylinders, diameter		500 mm. (19 11/16 inches)
Pistons, stroke		660 mm. (26 inches)
Boiler pressure		14 kgr. (199 lb. per sq. in.)
Diameter of coupled wheels		1450 mm. (4 ft. 9 5/64 in.)
Diameter carrying wheels		900 mm. (2 ft. 11 1/2 in.)
Total wheel base		10.115 m. (33 ft. 2 1/4 in.)
Grate area		5.10 m² (55 sq. feet)
Heating surface	firebox	18.930 m² (203.8 sq. feet).
	tubes	212.780 m² (2290.4 —)
	total	231.710 m² (2494.2 —)
Tubes	number	40 190
	diameter	125/133 mm. (1) 45/50 mm. (2)
	length	5.000 m. (16 ft. 3 in.).
Mean inside diameter of the barrel		1.800 m. (5 ft. 10 7/8 in.).
Mean tractive effort		20 700 kgr. (45 635 lb.)
Total empty weight		98.6 t. (97.1 Engl. tons)
Total weight in working order		107.2 t. (105.5 Engl. tons).
Adhesive weight		90.8 t. (89.4 Engl. tons).

(1) (5 5/64 in. — 5 15/64 in.) (2) (1 49/64 in. — 1 31/32 in.)

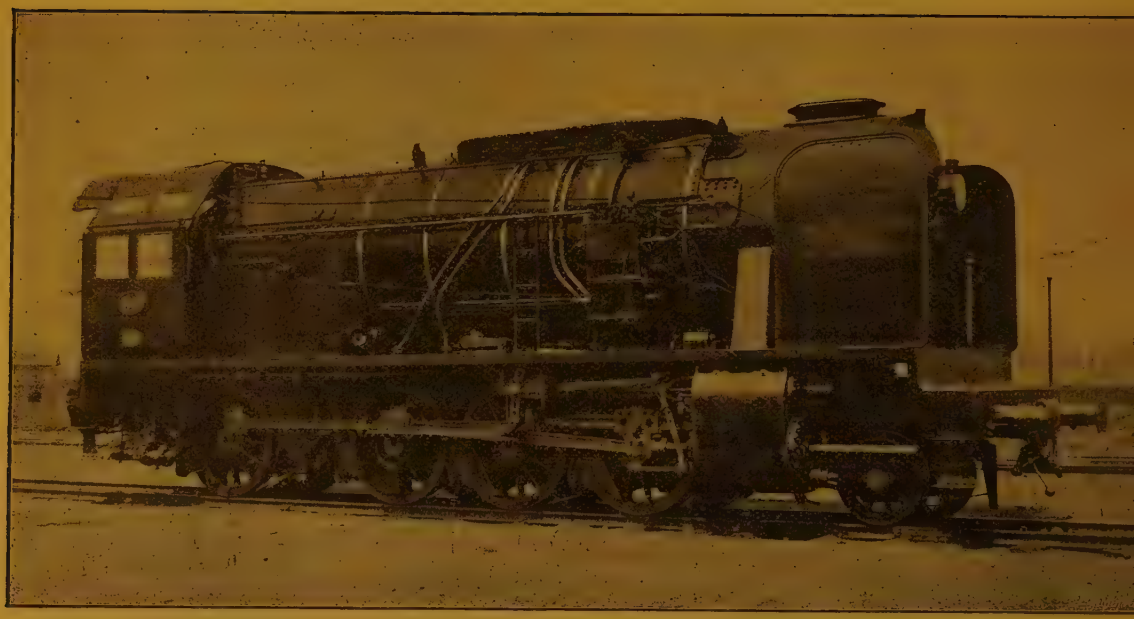


Fig. 2.

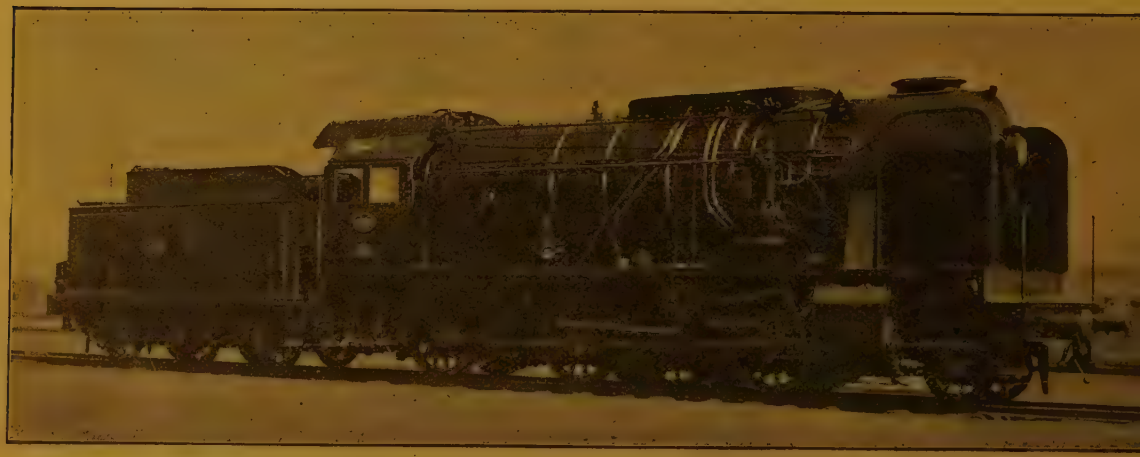


Fig. 2*a*.

to run over lines the loading gauge of which limits the maximum height above rails to 4.280 m. (14 ft. 1/2 in.) this dimension was followed by the designers. In addition the lower part of the locomotive has been so designed as to come within a loading gauge considerably tighter than that of the Belgian State, so as to leave room for the possible installation of certain track or signalling equipment.

The need for not giving the locomotive an excessive total wheel base, for using a firebox of large size extending over the main side frames, whilst at the same time obtaining a suitable distribution of weight over the wheels, resulted in the tubes being given a length of 4.500 m. (14 ft. 9 5/32 in.) between the tube plates, and to the barrel being given a diameter of 2 m. (6 ft. 6 3/4 in.).

The distance between the third and fourth pairs of wheels was increased to 2.650 m. (8 ft. 8 23/64 in.).

From the construction point of view, and when compared with the class 36, the new class 35 locomotive has considerable interest because it has the same power as that of the class 36 whilst at the same time being much more simple. Thanks to the allowable increase in the axle load, the class 35 has a greater adhesive weight than that of the class 36 with one less pair of coupled wheels which results in a total wheelbase of 8.500 m. (27 ft. 10 43/64 in.) instead of 10.115 m. (33 ft. 2 1/4 in.).

In addition the new type has only two outside valve gears instead of four, two of which are inside, fitted on the class 36.

Figure 3 shows the layout of the class 35 locomotive and gives the leading dimensions.

DETAILED DESCRIPTION.

Boiler. — The boiler pressure is 14 kgr. (199 lb. per sq. inch.).

The centre line of the barrel is 2.95 m. (9 ft. 8 1/4 in.) above the rail level. It consists of two rings, 19.5 mm. (0.768 inch) thick, the minimum inside diameter being 1.999 m. (6 ft. 6 3/4 in.).

The rings are made of 40-kgr. (25.4 Engl. tons per sq. inch) steel, with a minimum elongation of 27 %.

The firebox is moderately deep, and extends over the frame.

The grate which is lightly sloped towards the front end is 2.880 m. (9 ft. 5 3/8 in.) long, and 1.760 m. (5 ft. 9 9/32 in.) wide, which gives an area of 5.07 m² (54.6 sq. feet).

The grate is of the *shaking* type and a fire drop operated by a hand lever is fitted at the forward end. The dimensions of the grate being approximately the same as those of the 36 class, the same details have been used for the grate, with the object of standardisation.

The inside firebox, of copper, is of the ordinary type, without combustion chamber. The tube plate is 30 mm. (1 3/16 inches) thick, the sides of the firebox, 16 mm. (5/8 inch). The crown of the firebox has a slope towards the back end of 20 mm. per m. (1 in 50). The brick arch is built of bricks laid on four mild steel arch tubes 67/76 mm. (2 41/64 in. — 2 63/64 in.) diameter.

The tubes are 4.50 m. (14 ft. 9 5/32 in.) long between the tube plates; there are 182 ordinary smoke tubes, 45/50 mm. (1 49/64 in. — 1 31/32 in.) diameter, and 43 flues, 128/137 mm. (5 3/64 in. — 5 25/64 in.) diameter, for the superheater elements.

The firebox is fitted with two standard fire hole doors, with horizontal

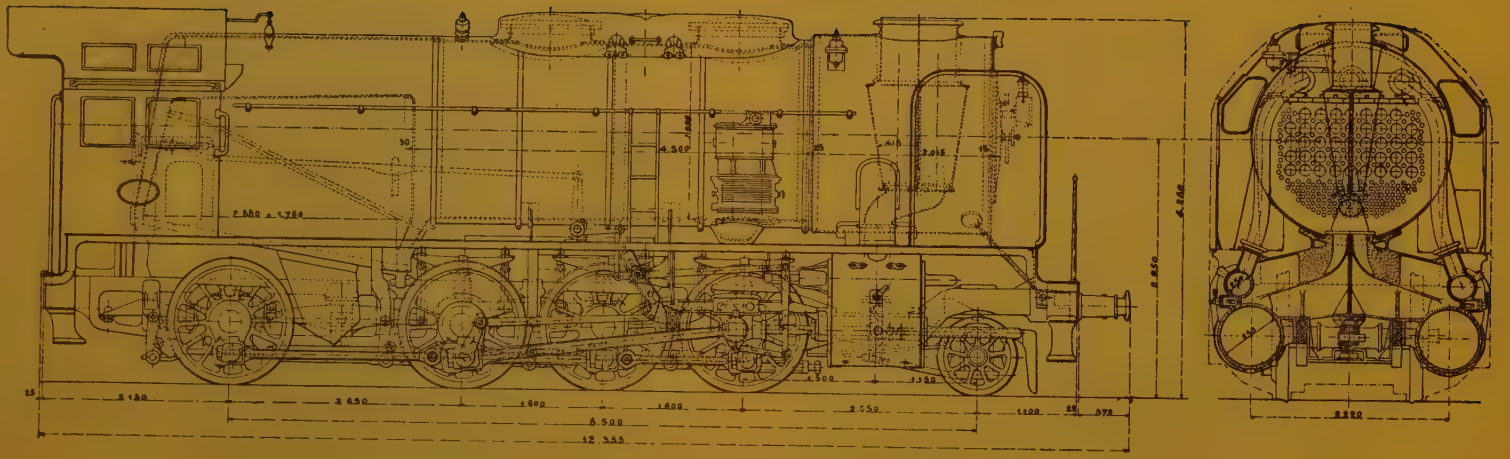


Fig. 3. — Class 35 goods locomotive.

Leading dimensions.

TYPE OF LOCOMOTIVE : « CONSOLIDATION » 2-8-0.

Motion	2 Cylinders :	
	Diameter . . . . (*d*)	650 mm. (25 5/8 in.).
	Stroke . . . . . (*l*)	720 mm. (28 3/8 in.).
	Diameter of coupled wheels (*D*)	1 450 mm. (4 ft. 9 5/64 in.).
	— carrying wheels . .	900 mm. (2 ft. 11 1/2 in.).
Boiler	Pressure . . . . . (*p*)	14 kgr. (199 lb. per square inch).
	Grate :	
	Length	2.880 m. (9 ft. 5 3/8 in.).
	Width	1.760 m. (5 ft. 9 9/32 in.).
	Area.	5.069 m² (54.6 sq. feet).
	Distance between tube plates.	4.500 m. (14 ft. 9 5/32 in).
	Tubes :	
	182 tubes	45/50 mm. (1 49/64 in. — 1 31/32 in.).
	43 flues.	128/137 mm. (5 3/64 in. – 5 25/64 in.).
	4 water tubes carrying arch .	67/76 mm. (2 41/64 in. — 2 63/64 in).
	Superheater elements . . .	30.5/38 mm. (1 7/32 in. — 1 1/2 in.).

Boiler, heating surface :	
Firebox	20.07 m² (342.5 sq. feet).
Tubes	193.59 m² (3 303.4 sq. feet).
Total . . .	213.66 m² (3 645.9 sq. feet).
Tractive effort $T = 0,75 \times \frac{pd^2l}{D}$	22 028 kgr. (48 561 lb.).
Weight of the locomotive in working order :	
Leading truck	15.2 t. (14.95 Engl. tons).
2nd pair of wheels	22.9 t. (22.54 — —
3rd — —	22 9 t. (22.54 — —
4th — —	23.7 t. (23.32 — —
5th — —	23.7 t. (23.32 — —
Total . . .	108.4 t. (106.67 Engl. tons).
Empty weight	100 t. (98.42 Engl. tons).
Adhesive weight (A)	93.2 t. (91.72 Engl. tons).
Ratio : $\frac{T}{A} =$	1 : 4.23.

hinged pins, of the automatic self-closing type.

The boiler is fitted with two Dewrance water gauges, with fusible plugs, and two Coale safety valves 89 mm. (3 1/2 inches) in diameter.

The boiler is normally fed with feed water by means of a No. 12 Davies & Metcalfe, type H, exhaust steam injector, carried on the right hand (fireman) side.

An ordinary No. 13 non-lifting pattern injector is fitted on the left side.

The delivery pipes feed into the leading dome in which there is a scale collecting device of the Reichsbahn type.

The exhaust is double; it consists of two blast pipes 130 mm. (5 1/8 inches) in diameter, each discharging into a cylindrical chimney 420 mm. (28 1/2 in.) in diameter. The leading dimensions of the front end are the same as those tried out successfully on the class 36 locomotives.

The superheater is of the Schmidt type. The superheater elements are 30.5/38 mm. (1 7/32 in. — 1 1/2 in.) in diameter, and are of the double bend type, the spear end nearest the firebox being placed 470 mm. (18 1/2 inches) from the tube plate.

For experimental purposes, two engines have been fitted with elements in which the return bend is brought back to the smoke box, the other two having the return bend of the elements shortened so that they stop at 3.450 m. (11 ft. 3 53/64 in.) from the firebox.

There are 43 elements and 182 ordinary smoke tubes of 45/50 mm. (1 49/64 in. — 1 31/32 in.) diameter, that is one element for every 4.3 ordinary smoke tubes.

A Knorr type snifting valve is placed on the saturated steam side of the header and is automatically operated by a small compressed-air cylinder in which air is admitted at the same time as into the small cylinders controlling the cylinder by-passes. This valve, therefore, opens automatically when the regulator is shut, and admits fresh air into the superheater elements. This admission of air is assisted by the injection of steam, controlled from te çab. This jet of steam acts in fact as an exhaust nozzle in a cylindrical passage arranged in the header. The mixture of steam with the air has the advantage of reducing the carbonisation of the lubricating oils.

The jet of steam is shut off only when standing.

The regulator placed in the back dome is of the ordinary balanced valve type, and is made of cast iron; the operating gear, carried outside the boiler, is worked by a hand lever placed above the reversing screw.

The boiler at the front end is secured by the smokebox to the cylinder block, at the front end of the firebox foundation ring; it is carried on two expansion brackets of large dimensions and in addition, on three flexible plate supports, the last placed behind the foundation ring.

Motion. — The cylinders have a diameter of 650 mm. (25 5/8 inches) and a stroke of 720 mm. (28 3/8 inches). The theoretical average tractive effort $T = 0.75 \frac{pd^2l}{D} = 22\,028$ kgr. (48 561 lb.).

The total adhesive weight being 93.2 t. (91.7 Engl. tons), we therefore have a ratio of tractive effort to adhesive weight of 1 : 4.23.

The cylinders are of the American type; their horizontal centre line coincides with that of the locomotive, and their upper part carries the smokebox.

The cylinders are both alike, and so can be used either for the right or the left hand; they are fitted with liners of a harder cast iron than that of the cylinder blocks proper.

The diameter of the piston valves is 250 mm. (9 27/32 inches); they are fitted with two narrow rings on the exhaust side and three on the admission side, an arrangement which is used on many foreign engines and which should ensure tightness.

The pistons are of cast steel, having a tensile strength of 50 kgr. (31.7 Engl. tons per sq. inch), with a minimum elongation of 14 %. These pistons are coned and tail rods are fitted in an air-tight sleeve of the Belgian State pattern. The piston rod packing is of the « Crescent » type.

The cylinder covers are fitted with release valves 85 mm. (3 11/32 inches) in diameter. The drain cocks are fitted with stainless steel valves, controlled from the cab by means of compressed air.

The cylinders are lubricated by a « Detroit » displacement lubricator; the lubricator has five leads with an oil level indicator and a valve controlling the oil feed. The five feeds are used as follows: one to each of the piston valves, one to each of the piston tail rods, and one to the brake pump.

The connecting rods are 3.100 m. (10 ft. 2 in.) long and drive the third pair of coupled wheels. The connecting and coupling rods are fitted with pin type oilers.

Walschaerts valve gear is fitted; it gives a maximum cut-off of 84 % in fore gear, and 70 % in back gear.

The leading dimensions of the valve gear are as follows :

	mm.	*inches.*
Diameter of piston valve.	250	9 27/32
Width of port	55	2 11/64
Steam lap	40	1 37/64
Exhaust lap	0	0
Maximum valve travel .	199.5	7 27/32

The weigh bar shaft is controlled by screw reversing gear of the usual type with an indicator showing the degrees of cut-off.

In order to make the reversing gear as easy as possible to work, the driver can, at will, admit air into a special cylinder acting on a lever keyed to the weigh bar shaft.

Frame. — The frames are of the « bar » type; they are cut out of rolled plate, their thickness being 114 mm. (4 31/64 inches).

They are stayed together at the leading end by the cylinder block. In addition, the frame is stayed, at the front end by a solid cast steel stay, which also acts as a guide for the centre bearing of the leading truck, at the back end by a cast steel drag box carrying the coupling and draw gear and by three intermediate stays, one of which carries the boiler support at the front end of the fire box, the other two acting as supports for the barrel of the boiler.

Trucks. — The leading truck is of the American type with triangular links. The load comes on to it through a longitudinal lever, the pivot of the lever being carried on the cylinder block.

The play given to the truck is 94 mm. (3 45/64 inches) on both sides of the centre. The centering device has an initial load of 2 500 kgr. (5 512 lb.) and a maximum of 6 940 kgr. (15 953 lb.).

Spring gear. — The springs of the coupled wheels are 950 mm. (3 ft. 1 3/8 in.) long, and consist of 17 ribbed plates 120 × 10 mm. (4 23/32 in. ×3/8 inch).

The leading truck boxes are fitted with two concentric coil springs.

The springs of the two first pairs of coupled wheels are connected by equalising levers to the pivot of the leading truck; furthermore, the springs of the two last pairs of coupled wheels are connected on each side by equalising levers. The whole arrangement therefore gives a three-point suspension.

The springs of the first three pairs of coupled wheels are carried above the axle boxes, the load being transmitted to the latter by links on each side of the frame, following the American practice.

The springs of the fourth pair of coupled wheels which come under the firebox are reversed and are carried in the frame; this arrangement requires the use of a special equaliser to transfer the load on to the axle boxes.

Wheels. — The tyres of the coupled wheels are 81 mm. (3 3/16 inches) thick. Up to the present the standard thickness of locomotive tyres has been 76 mm. (3 inches); this thickness was increased to 81 mm. (3 3/16 inches) on account of the heavy loads on the wheels. The tyres of the leading trucks are the standard thickness of 76 mm.

In order that the engine may run round curves of 120 m. (6 chains), radius, the tyres of the second and third pairs of coupled wheels have the flanges reduced in thickness by 15 mm. (19/32 inch). None of the coupled wheels has been given side play.

The leading dimensions of the crank and coupling rod pins are given in the table below.

Axles.

DESCRIPTION.	*Diameter on the tread.* mm.	*d* mm.	*d* inches.	*l* mm.	*l* inches.	*Centre to centre.* mm.
Leading truck :						
1st pair of wheels	900 (2 ft. 11 1/2 in.)	190	7 1/2	360	14 3/16	1 000 (3 ft. 3 3/8 in.)
Coupled axles : 2nd — —	1 450 (4 ft. 9 5/64 in.)	260	10 1/4	320	12 9/16	1 050 (3 ft. 5 11/32 in.)
Coupled axles : 3rd — —	1 450 (4 ft. 9 5/64 in.)	260	10 1/4	320	12 9/16	1 050 (3 ft. 5 11/32 in.)
Coupled axles : 4th — —	1 450 (4 ft. 9 5/64 in.)	290	11 7/16	320	12 9/16	1 050 (3 ft. 5 11/32 in.)
Coupled axles : 5th — —	1 450 (4 ft. 9 5/64 in.)	260	10 1/4	320	12 9/16	1 050 (3 ft. 5 11/32 in.)

Crank pins.

DESCRIPTION.	*d* mm.	*d* inches.	*l* mm.	*l* inches.	*Distance between wheel centres.* mm.
Connecting rods	200	7 7/8	185	7 9/32	2 200 (7 ft. 2 5/8 in.)
Coupling rods :					
1st pair of coupled wheels	140	5 1/2	100	3 15/16	1 880 (6 ft. 2 in.)
2nd — —	140	5 1/2	100	3 15/16	1 905 (6 ft. 3 in.)
3rd — —	220	8 11/16	130	5 1/8	1 905 (6 ft. 3 in.)
4th — —	140	5 1/2	100	3 15/16	1 880 (6 ft. 2 in.)

The first pair of wheels is interchangable with the fourth.

The axles of the coupled wheels are bored out with a 75-mm. (2 61/64-inch) hole.

Balancing. — The maximum speed allowed for this type of locomotive is 65 km. (40.4 miles) an hour. The reciprocating parts have been balanced by counter balance weights in the wheel

centres. The whole of the revolving masses has been balanced, and 41.5 % of the reciprocating parts. This balancing limits the hammerblow on the rail, at the maximum speed considered, to 15 % of the static load on the wheel.

Brakes. — The locomotive is fitted with the Westinghouse automatic and direct acting brakes. The leading truck wheels are the only ones not braked. The total braking effort equals 65 % of the adhesive weight, and is obtained by means of two brake cylinders 406 mm. (16 inches) in diameter, carried on a cross stay immediately behind the first pair of coupled wheels.

The brake pump is of the Westinghouse Company's cross compound type, and is fed with superheated steam. In order to get this, the saturated steam, the admission of which is controlled from the cab by a valve of the ordinary type, passes through a superheater element reserved for this purpose, and the steam in this way is superheated when it gets to the pump. The pump is in this way protected from the drawbacks resulting from the use of steam which is generally very wet, both as regards upkeep and as regards consumption.

Other fittings. — The locomotive is also fitted with : a « Superior » type soot blower for cleaning the tubes; compressed air sanding-gear of the Gresham type, sanding all the coupled wheels; steam heating equipment; a Dilling valve for injecting water into the smoke box, into the ash pan, and for watering the coal.

At the front end, the engine is fitted with the Reichsbahn type of smoke deflectors plates.

So as to give the driver and fireman some degree of comfort, the cab is fitted with two lift-up spring seats, and can be closed at the back by means of a sail cloth curtain.

Tender.

The tender coupled to the class 35 locomotive is of the six-wheeled rigid-wheelbase type, and carries 24 m^3 (5 280 Br. gallons) of water, and 7 tons of coal. This tender only differs in a few details from the type 18 tenders of Belgian State Railways first built in 1910, for locomotives of the 10 and 36 classes. It has also since been used for the 33, 37 and 38 classes of the Belgian National Railway Company's locomotives.

The number of these tenders at the present time is 83.

Figure 4 gives a diagram of the tender with its leading dimensions.

The improvements made to these new tenders as compared with the original type are the following :

The body is fitted at the top with heightening plates which enable the briquettes to be more easily loaded; the filling hole has been enlarged so that water can be taken more quickly at the water colums; in addition the engine men's lockers have been better arranged. The gear working the feed water cocks has also been improved.

The spring gear consists of six springs 950 mm. (3 ft. 1 3/8 in.) long, having twelve plates 90 × 13 mm. (3 35/64 in. × 33/64 in.), and has been modified by connecting the springs of the two back pairs of wheels by equalisers. An interesting arrangement has been applied to the journals and bearings of the axles to reduce the considerable longitudinal thrusts, which are developed between the

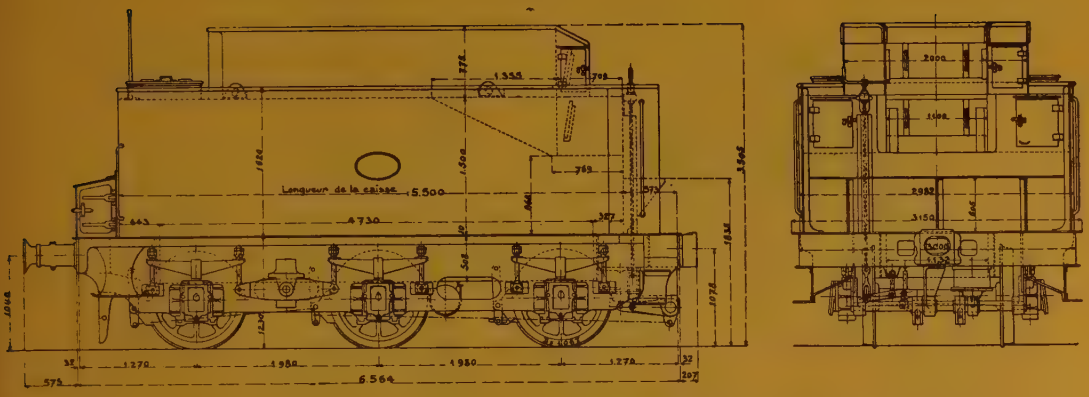


Fig. 4. — Type 24 tender.

Explanation :

Diameter of wheels	1 067 mm.	(3 ft. 6 in.).
Water	24 000 l.	(5 280 Br. gallons).
Coal	7 000 kgr.	(15 430 lb.).
Weight on leading pair of wheels	18 200 kgr.	(40 125 lb.().
Weight on middle —	18 300 kgr.	(40 345 lb.).
Weight on trailing —	18 300 kgr.	(40 345 lb.).
Total weight in working order	54 800 kgr.	(120 815 lb.).
Weight, empty	23 800 kgr.	(52 470 lb.).

journal and the bearing when passing through curves.

In the new design shown in figure 5, the journal collar has been done away with, and the thrust of the wheel is transmitted by the end to a segmental shaped wall forming part of the bearing; this latter is in addition secured in the box in the usual manner. The bearing surface of the bearing is of white metal, of the following composition :

Lead	74
Antimony	15
Tin	10
Copper	1

Tests carried out for more than three years with this new arrangement applied to older tenders, have given very satisfactory results, both as regards wear of the bearings, and as preventing heating. These tests have shown that the cylindrical surface of the bearing has to take only small loads, and that attention should be given entirely to the surfaces that have to take the longitudinal thrusts. The area offered by the usual design of the collar does not stand up well under the considerable thrust, and so must be considered a serious cause of heating.

Dynamometer car tests.

Locomotive No. 5601, of the 35 class, which was delivered by the Cockerill Works in May 1930, has undergone a series of dynamometer car tests on the Schaerbeek-Libramont section of the Luxemburg line.

As is well known, this line has long sections with a gradient of 16 mm. per metre (1 in 62), and the station at Libramont is the highest point of the line.

The weight of the train was gradually increased until it reached 730 t. (718 Engl. tons).

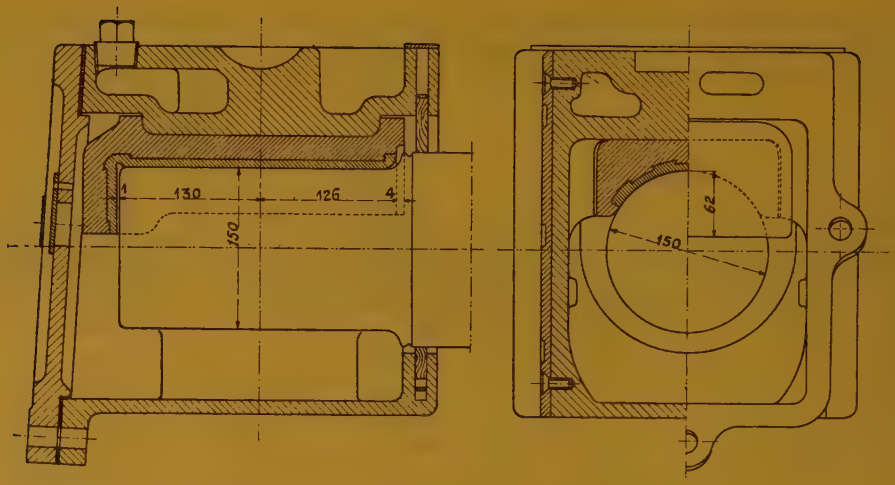


Fig. 5.

The results of the dynamometer-car tests on the 6 th June 1930 are given below :

Train No. 6832 between Schaerbeek and Libramont.

Load : 730 t., 33 vehicles, 68 pairs of wheels.

STATIONS.	TIME BETWEEN STATIONS. Shown in working table.	Actual.
Schaerbeek (F.) . .	...	...
Cinquantenaire . .	30 m.	21 m. 30 s.
Namur	105 m.	92 m.
Marloie	118 m.	96 m.
Jemelle	14 m.	13 m. 20 s.
Forrières	8 m.	9 m. 11 s.
Libramont . . .	75 m.	60 m. 33 s.
Total. . .	350 m.	292 m. 24 s.

The diagram, figure 6, shows the speed at the different points of the line.

The speed reductions that will be noticed at kilometres 63.5, 72.3 and 74.3 were made to see the rapidity with which the engine would regain its normal speed after a marked reduction of speed on a continuous rising gradient of 16 mm. per metre (1 in 62).

These tests show that the class 35 locomotive is able to attain and maintain on a gradient of 1 in 62 with a load of 730 t. (718 Engl. tons) a speed of 23 km. (14.3 miles) per hour.

The table below gives the dynamometer-car results as regards the work done, and the fuel and water consumptions during the test :

Total useful work at the tender draw bar	Tu :	3 315 ch./h. (3 270 H. P./hours).
Total indicated work	Ti :	4 070 ch./h. (4 015 —).
Ratio	$\frac{Tu}{Ti}$	0.815.
Total water used		39 640 l. (8 720 Br. gallons).
Total coal burnt		5 000 kgr. (11 020 lb.).

Water used per indicated H. P.-hour. . .	9.75 l. (2.75 Br. gallons).
Coal used per indicated H. P.-hour . . .	1.230 kgr. (2.75 lb.).
Coal used per useful H. P.-hour	1.510 kgr. (3.37 lb.).
Time the regulator was open.	3.67 hours.
Average indicated H. P.	1 110 ch. (1 095 H. P.).

It should be noted that these results are the averages obtained over the total trial run, and that the consumptions are the total consumptions of water and coal including those for lighting up and whilst standing.

The fuel consumption of the class 35 locomotive appears to be normal when compared with those obtained during previous tests on the same section of line.

When the engine is developing its maximum power the drop of pressure between the boiler and the steam chest is as a maximum 1 kgr. (14.2 lb. per sq. inch). The exhaust back pressure did not exceed 180 grammes per cm² (1.14 lb. per sq. inch).

The superheat temperature usually was 350° C. (662° F).

The resistance of the locomotive and tender with closed regulator is given at different speeds on the diagram, figure 7, which also shows the maximum indicated tractive effort the locomotive can maintain continuously.

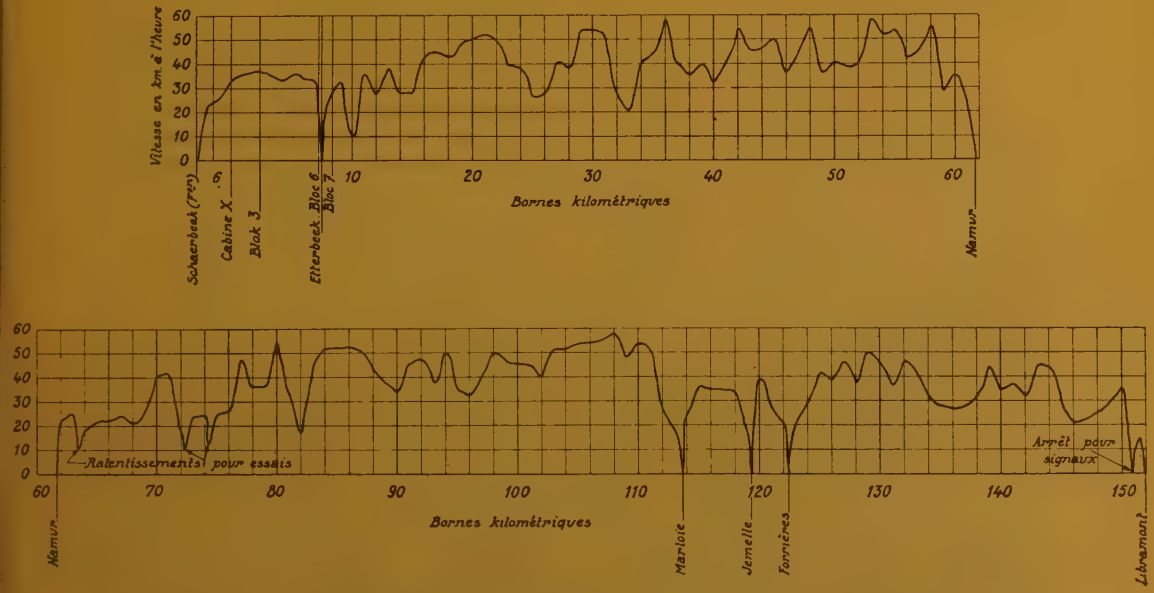


Fig. 6.

Explanation of French terms :

Vitesse en km. à l'heure = Speed, km. per hour. — Bornes kilométriques = Kilometre posts.
Ralentissements pour essais = Speed reduction tests. — Arrêt pour signaux = Signal stop.

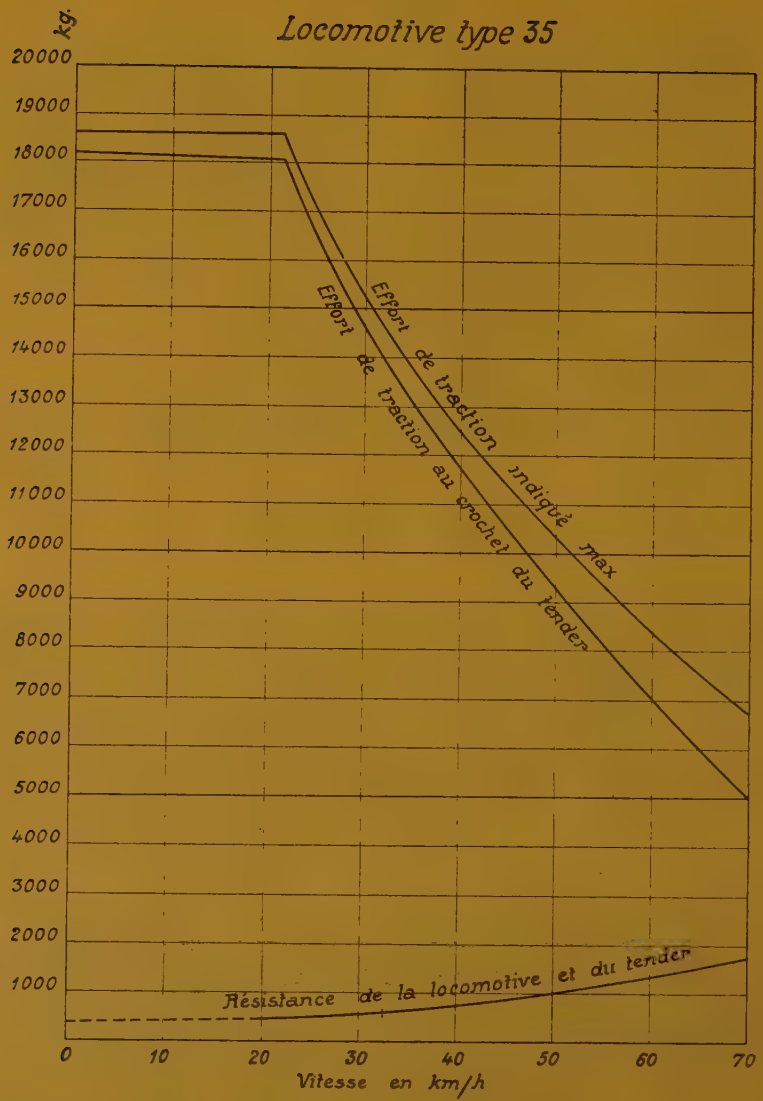


Fig. 7.

Explanation of French terms:
Effort de traction indiqué max. = Maximum indicated tractive effort. — Effort de traction au crochet du tender = Drawbar tractive effort. — Résistance de la locomotive et du tender = Resistance of the locomotive and tender. — Vitesse en km./h. = Speed in km. per hour

The resistance of the engine and tender with the regulator closed is shown to be very low, and this is due to the snifting valve on the collector and to the large by-pass passages with which the cylinders are fitted.

[621.132.8 (.44)]

Articulated locomotive working on the Somain-Anzin and Belgian Frontier Railway,

by P. BÂCLE,

Chief Operating Engineer of the Somain-Anzin and Belgian Frontier Railway.

Figs. 1 to 8, pp. 620 to 630.

Increased hauling power of the traction units on the great railway systems has led these systems to require the coalmines to make up their despatches into trains of up to 1 200 t. net and about 1 800 (1 181 and 1 772 Engl. tons) gross weight. To guarantee the haulage of these trains the Somain-Anzin & Belgian Frontier Railway, which is responsible for the removing of the output of the Anzin mines, had to put into service locomotives capable of developing a tractive effort of about 20 tons.

The high tractive effort required, coupled with the necessity of the locomotive being able to negotiate sharp curves, and run over old structures and therefore of no great strength, has made it essential to use many coupled axles, and directed the enquiries towards articulated locomotives.

The result of these investigations has been a simple expansion articulated tank engine, each unit having 12 coupled wheels, the whole of the weight being carried on the driving wheels (fig. 1). The usual objection to articulated locomotives, resulting from the rigid connection between the boiler and the trailing unit, which is most noticeable at high speeds, was not feared on the Anzin railway, as the speed of goods trains is in practice limited to 40 km. (25 miles) per hour.

(1) Translated from the French.

General description (fig. 2).

Though little used in France, articulated locomotives are well enough known to obviate the necessity of a minute description of the system. It is enough to recall to mind that these locomotives are usually formed of two driving units, usually of equal power, articulated together. The boiler is rigid attached to the back driving unit, and a part of its weight is carried on a slide on the front unit. A system of springs which forms a self centering device facilitates the passage of the back unit over curves, while preventing the excessive displacement of the boiler and overloading of the outside wheels. Articulated joints on the steam and exhaust pipes provide the necessary freedom to allow for the movement of the leading unit.

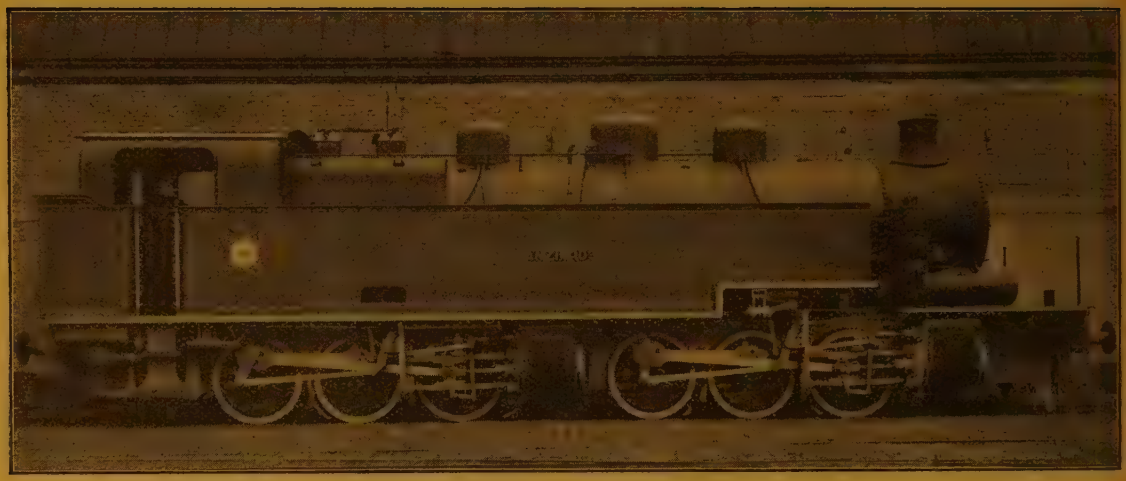


Fig. 1.

Leading dimensions of the locomotive.

Type of locomotive	060-060.
Grate :	
Length	2.440 m. (8 feet).
Width	1.600 m. (5 ft. 3 in.).
Area . . . . . G =	3.90 m² (42 sq. feet).
From top of grate to lower row of tubes.	550 mm. (21 11/16 inches).
Firebox :	
Height of crown above foundation ring :	
at the front.	1.610 m. (5 ft. 3 25/64 in.).
at the back	1.460 m. (4 ft. 9 15/32 in.).
Interior width :	
at the top.	1.440 m. (4 ft. 8 45/64 in.).
at the bottom	1.600 m. (5 ft. 3 in.).
Interior length :	
at the top.	2.394 m. (7 ft. 10 15/64).
at the bottom	2.440 m. (8 feet).
Thickness of the copper plates	14 mm. (35/64 inch).
Thickness of the copper tube plate	30 mm. (1 3/16 inch).
Tubes :	
Number	264.
Outside diameter	51 mm. (2 1/64 inch).
Thickness	3 mm. (1/8 inch).
Length between tube plates	6 000 m. (19 ft. 8 1/4 in.).

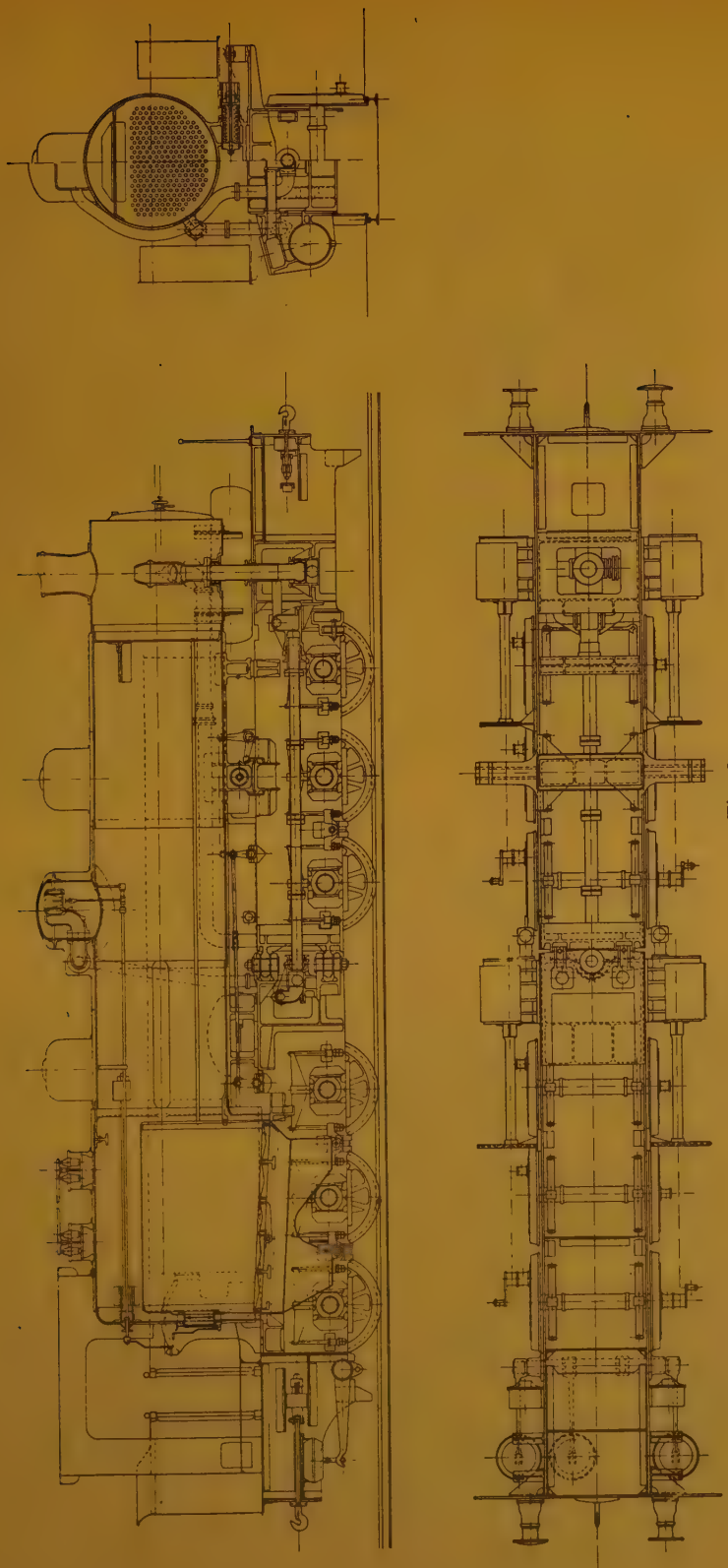
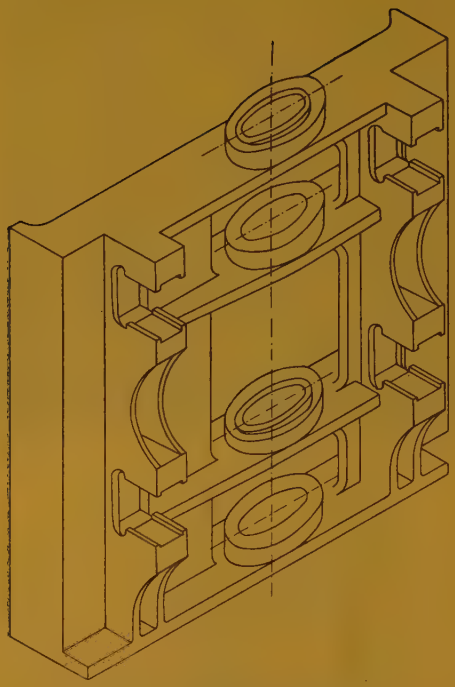
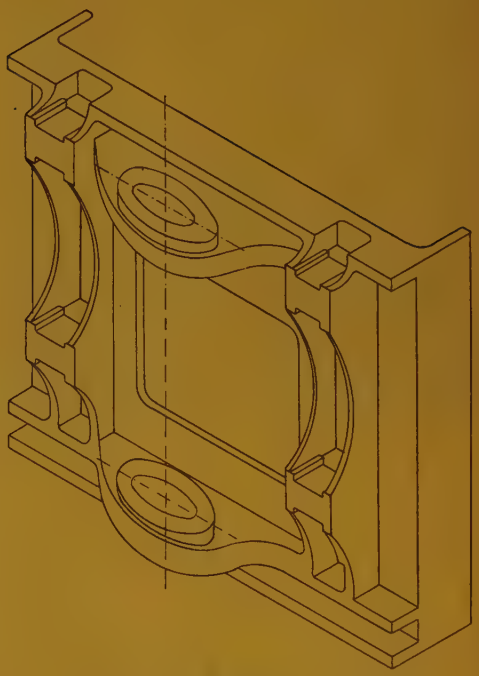


Fig. 2.



Frame stay at front of back truck.



Frame stay at back of front truck.

Fig. 3. — Coupling of the trucks. « La Meuse » patented system.

Heating surface :		
Firebox (above the grate)		14.00 m² (150.70 sq. feet).
Tubes (interior surface)	T =	223.98 m² (2 410.92 sq. feet).
Total	S =	237 98 m² (2 561.62 sq. feet).
Ratios	$\frac{S}{G}$ = 61.	$\frac{T}{F}$ = 16.
Boiler :		
Outer firebox casing :		
length		2.642 m. (8 ft. 8 in.).
width at the top		1.680 m. (5 ft. 6 5/32 in.).
width at the bottom		1.802 m. (5 ft. 11 in.).
Mean diameter of the boiler barrel		1.600 m. (5 ft. 3 in.).
Length of the boiler barrel		6.100 m. (20 ft. 5/32 in.).
Overall length of the boiler		8.742 m. (28 ft. 8 13/64 in.).
Height from rail level to boiler centre line. .		2.675 m. (8 ft. 9 5/16 in.).
Height from rail level to underside of the foundation ring		1.325 m. (4 ft. 4 5/32 in.).
Thickness of the barrel plates		17 mm. (43/64 inch).
Thickness of the firebox casings		17 mm. (43/64 inch).

Interior volume of the boiler	12 m³ (423.8 cubic feet).
Inside length of the smoke-box	1.475 m. (4 ft. 10 5/64 in.).
Inside diameter of the smoke-box.	1.634 m. (5 ft. 4 5/16 in.).
Pressure	13 kgr./cm² (184.9 lb. per sq. inch).
Diameter of the safety valves	102 mm. (4 inches).
Chimney :	
Inside diameter :	
at the top	490 mm. (19 1/4 inches).
at the choke	460 mm. (18 1/4 inches).
Height above the smoke-box	625 mm. (24 19/32 inches).
Section of the gas passage :	
Through the tubes $t =$	0.479 m² (742.45 sq. inches).
Section of the chimney at the smallest diameter $c =$	0.1662 m² (257.61 sq. inches).
Ratio $\frac{t}{c} =$	2.52.
Frame :	
Distance between frame plates.	1.250 m. (4 ft. 1 13/64 in.).
Minimum section of the frames above the boxes	1.450 mm² (22.475 sq. inches).
Total overall width	3.106 m. (10 ft. 2 9/32 in.).
Length of the locomotive over buffers.	14.400 m. (47 ft. 3 in.).
Mechanism :	
Number of cylinders.	4.
Diameter of cylinders	480 mm. (18 7/8 inches).
Stroke.	600 mm. (23 5/8 inches).
Section of cylinders $c =$	0.1809 m² (280.4 sq. inches).
Volume swept out by piston $V =$	0.1085 m³ (3.790 cubic feet).
Mean clearance volume. $v =$	0.0055 m³ (0.194 cubic foot).
Ratio $\frac{100v}{V} =$	5.1.
Distance between the cylinder centres.	2.084 m. (6 ft. 10 in.).
Length of the connecting rods	2.600 m. (8 ft. 6 23/64 in.).
Radius of crank-pins	0.300 m. (11 13/16 inches).
Ratio of length of driving rod to crank radius.	8.66.
Valve motion :	
Distance between valve rods	2.290 m. (7 ft. 6 5/32 in.).
Angle of advance of the eccentrics.	90°.
Eccentrics radius	150 mm. (5 29/32 inches).
Maximum movement of valve from centre position :	
forward	60 mm. (2 23/64 inches).
backward	62 mm. (2 7/16 inches).
Slide valves :	
Type	flat.
Steam-lap	27 mm. (1 1/16 inch).

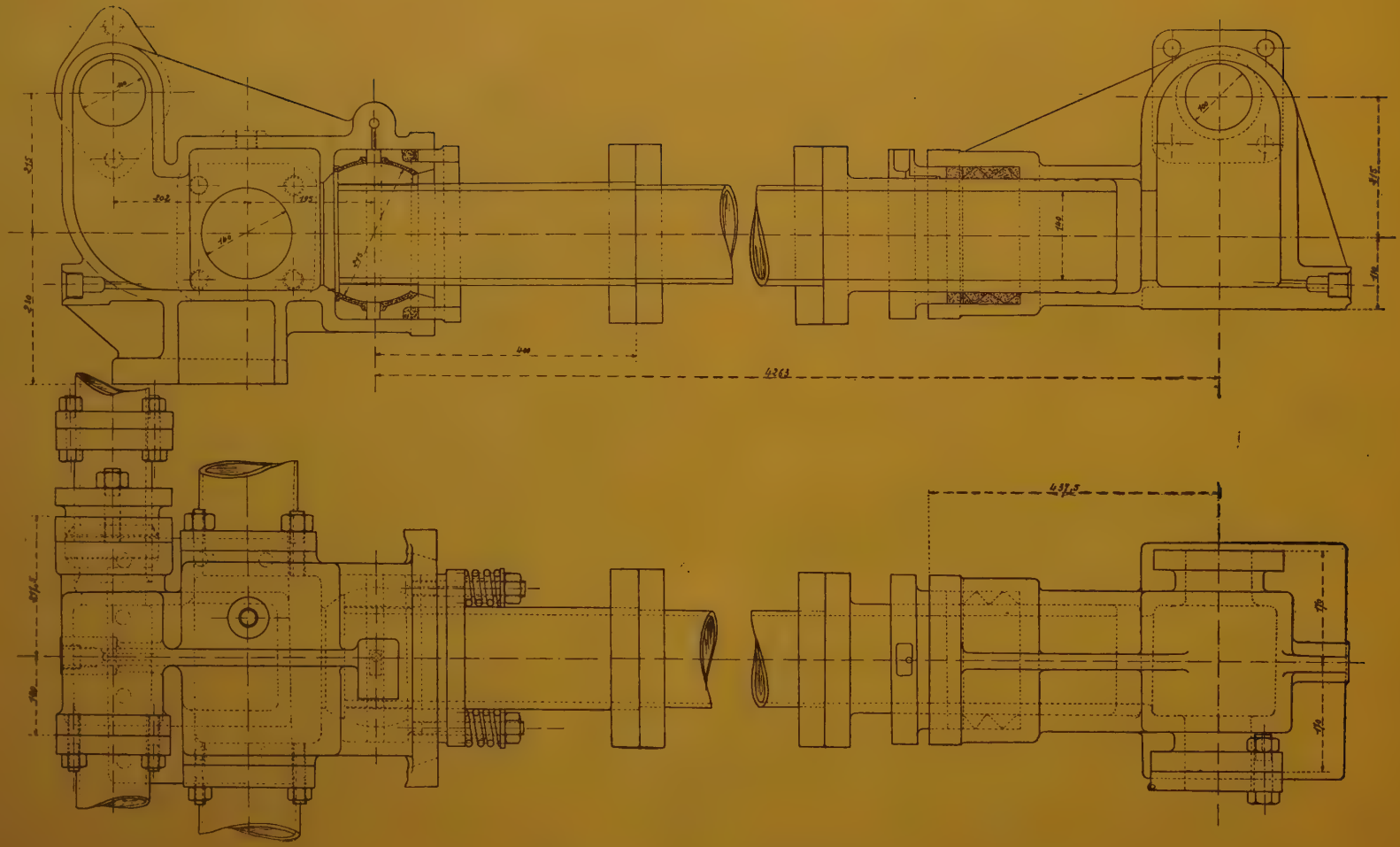


Fig. 4. — Arrangement of steam pipe.

Exhaust-lap	1 mm. (0.039 inch).
Total capacity of the tanks	9 m³ (1 981 gallons).
Capacity of the coal-bunker	2 000 kgr. (4 400 lb.).

Weights :

Weight empty	88 000 kgr. (194 000 lb.).
Weight loaded with 0.20 m. (8 inches) of water above the top of the firebox, 9 m³ (1 981 gallons) of water in the tank, 2 000 kgr. (4 400 lb.) of fuel in the bunker, 800 kgr. (1 760 lb.) of fuel in the firebox, 400 kgr. (880 lb.) of sand in the sand boxes and 300 kgr. (660 lb). of tools	103 200 kgr. (227 520 lb.).

Load on each axle :

Leading truck	1st pair of wheels.	17 200 kgr. (37 920 lb.).
	2nd pair of wheels.	17 200 kgr. (37 920 lb.).
	3rd pair of wheels.	17 400 kgr. (38 360 lb.).
Trailing truck	4th pair of wheels.	17 200 kgr. (37 920 lb.).
	5th pair of wheels.	17 000 kgr. (37 480 lb.).
	6th pair of wheels.	17 200 kgr. (37 920 lb.).
Adhesive weight		103 200 kgr. (227 520 lb.).
Tractive effort		19 850 kgr. (43 760 lb.).
Power in kw.		1 250 kw.

Particular features of the locomotive.

In building this locomotive certain particular arrangements had to be devised which deserve special mention :

Coupling of the two trucks.

Running through curves, over gradients and over irregularities in the track causes the leading truck to assume positions which vary relatively to the boiler, which is rigidly secured to the back truck. Although these relative displacements are small, they must not be lost sight of as it is necesary to avoid excessive stresses being set up between parts in contact.

The coupling together of the two trucks has been given special attention by the Meuse Company at their works at Liége and the arrangement adopted has been patented by them. This arrangement consists of two fixed stays; one at the front of the back truck, the other at the back of the front truck (fig. 3). The back truck stay has an eye at the top and another at the bottom, and two side jaws into which they engage : firstly the single eye; and secondly the side projecting lugs on the leading truck stay. A double pin, passing through the upper and lower eyes, provides the vertical axis of rotation. A few millimetres play between the jaws and the projecting lugs gives the leading truck sufficient vertical movement.

Steam and exhaust pipe connections of the leading truck.

The necessary articulations in the steam and exhaust pipes haves been

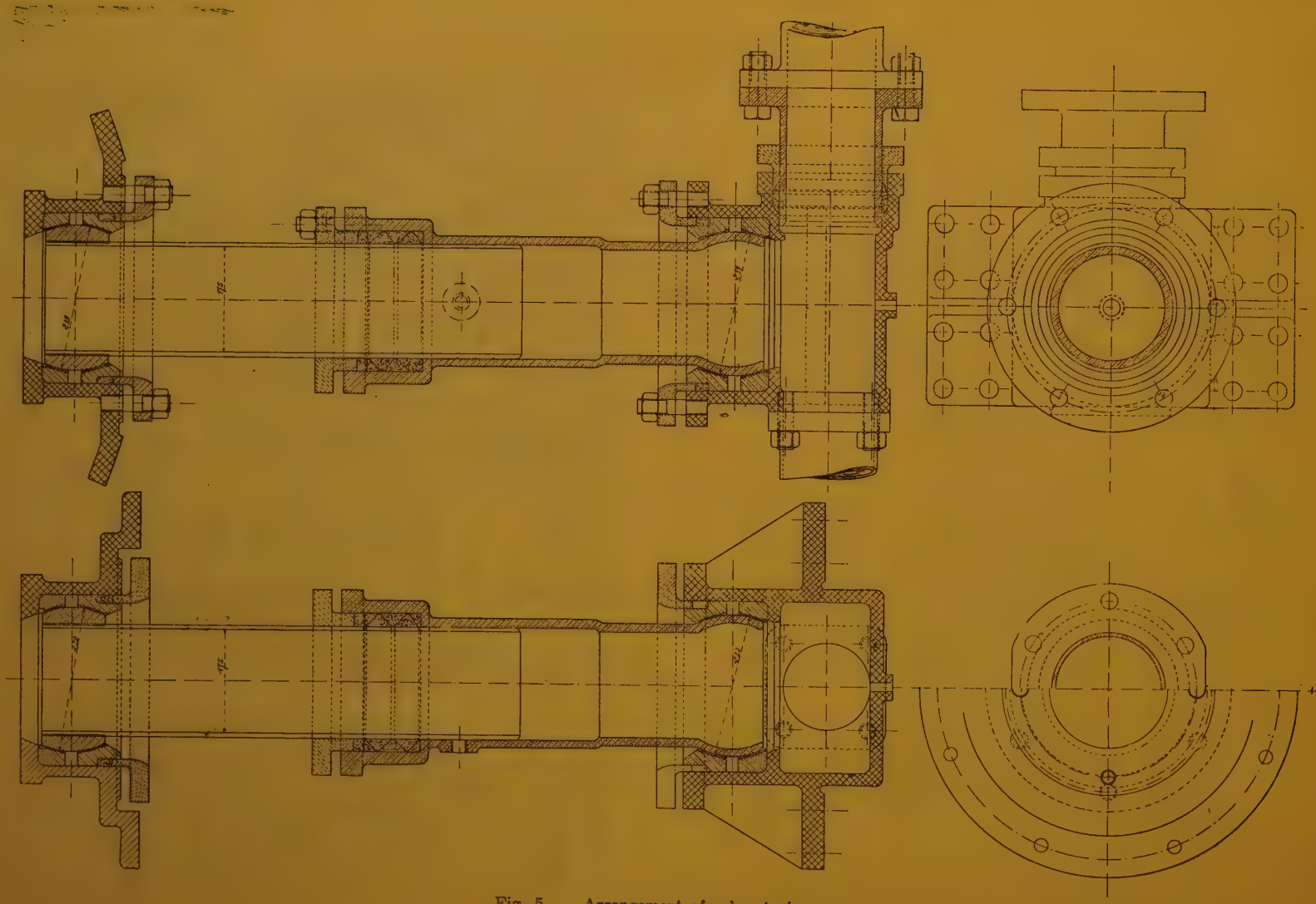


Fig. 5. — Arrangement of exhaust pipe.

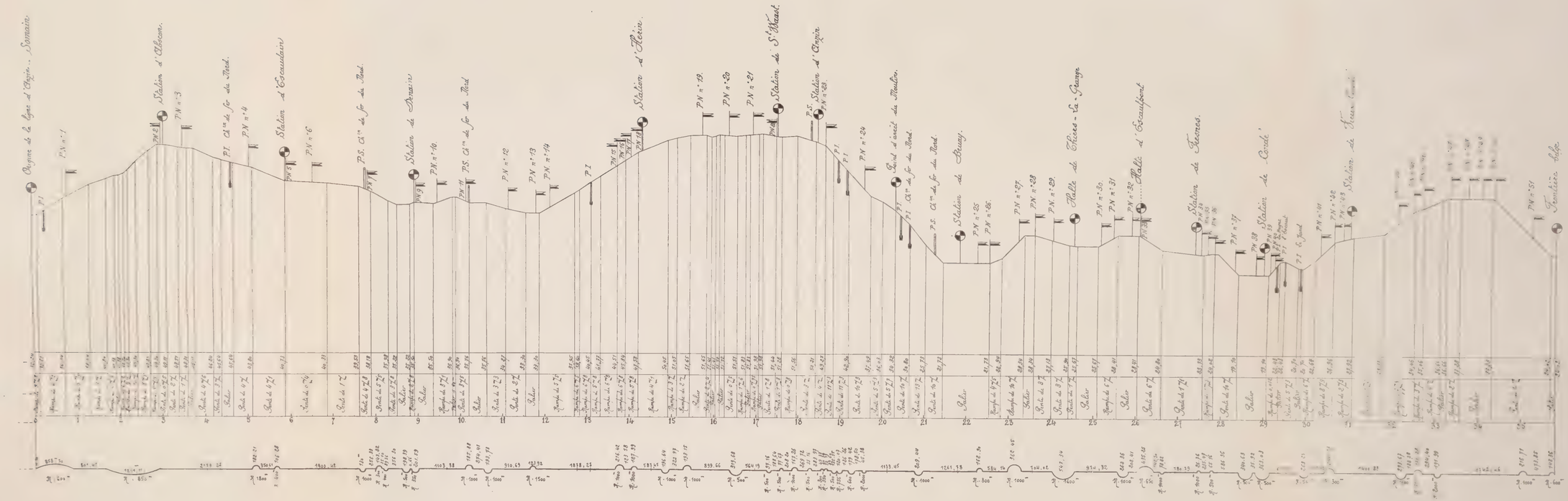


Fig. 7. — Anzin Railway. Longitudinal section.

Explanation of French terms:

Palier = level. — Pente = down gradient P N = level crossing. — Rampe = up gradient.

LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

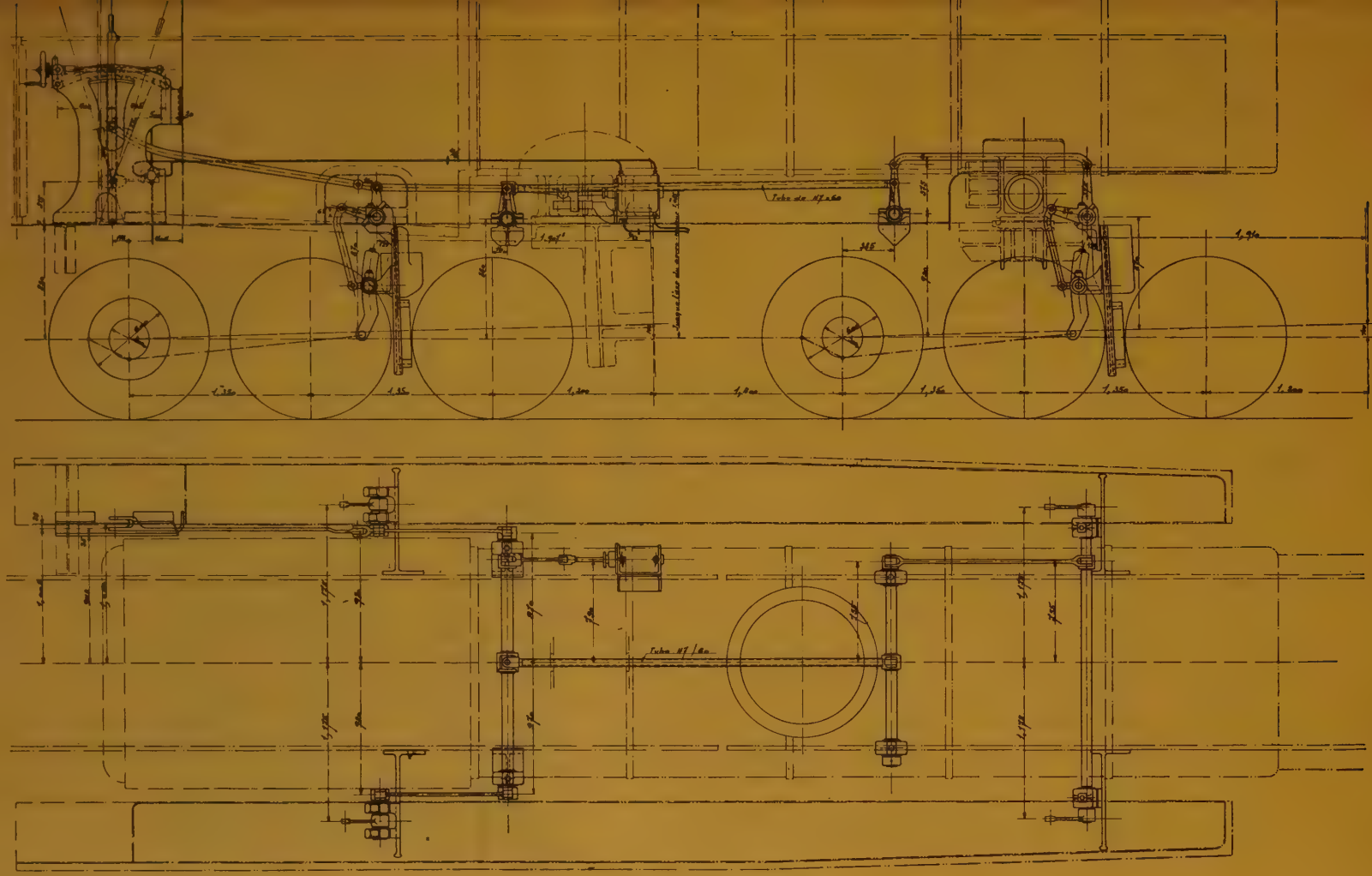


Fig. 6. — Reversing gear.

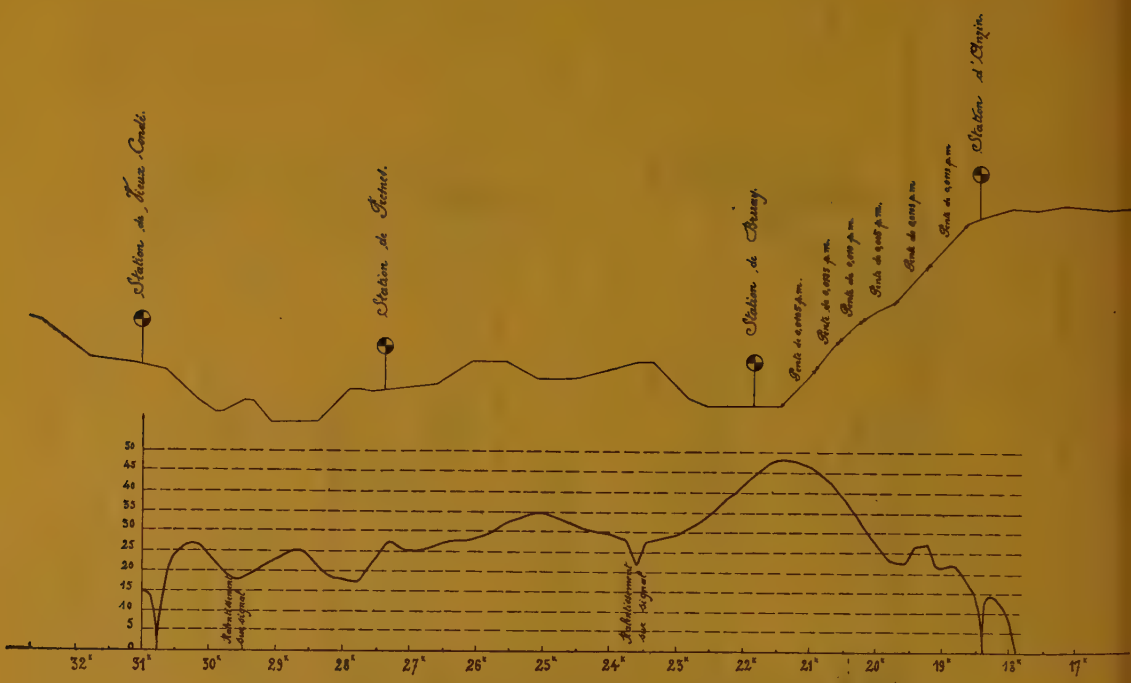


Fig. 8. — Train 110, 26 May 1930, from Vieux-Condé to Anzin. — Load : 1 000 Engl. tons.
Engine No. 102, without assisting engine between Bruay and Anzin.

Explanation of French terms:
Ralentissement sur signal = Signal check.

obtained by means of spherical joints in bronze, and sliding sleeves filled with metallic packing (figs. 4 and 5). The spherical joints are pressure-lubricated; the degree of tightness depends upon the accuracy of machining.

Working of the reversing gear.

Walschaerts valve gear is used. To facilitate the driver's work, handling the reversing gear and thereby moving the four sliding valves, a small servo-motor is fitted. This servo-motor simply consists of a piston of suitable diameter, worked by steam from the boiler, and acting directly on the intermediate shafts. Forked rods allow for the necessary play in working the motion of the leading truck wheels (fig. 6).

Electric lighting.

A Sunbeam turbo-alternator of 500 watts, giving 15 amperes at 32 volts, supplies the current needed for lighting the front and back lights and the lamps in the cab. It can also if required light the coaches of a passenger train.

Results.

Three locomotives of this type were put into service on the Anzin Railway at the beginning of 1930. One of them had run 65 000 km. (40 400 miles) up to

the 28 th February 1931. These locomotives are capable of working trains of 1 500 tons, over the section shown in figure 7, in ordinary service, provided they are assisted by a banking engine between Bruay and Anzin. On this section, where the gradients reach 13 in 1 000 (1 in 77) with curves as sharp as 300 m. (15 chains) radius, the tonnage has to be reduced to 930 t. (915 Engl. tons) in normal service. Figure 8 reproduces the speed record diagram of a train of 1 012 t. (1 000 Engl. tons), drawn by one of these locomotives, on the section between Vieux-Condé and Anzin. The gradient between Bruay and Anzin, traversed at 47 km. (29.2 m. p. h.) was done without a helping engine.

The locomotive can be run through curves of 75 m. (3 3/4 chains) radius without difficulty. On a curve of 150 m. (7 1/2 chains), the lateral displacement of the boiler on the leading wheels is 120 mm. (4 23/32 inches).

No derailment due to faulty construction has yet occurred.

The average consumptions per kilometre are 24 kgr. of fuel and 80 gr. of oil (142 lb. and 4.53 ounces per mile) respectively. The boiler evaporates 7.3 litres of water per kgr. (0.73 Br. gallon per lb.) of coal.

[621 .33 (.436)]

Electrification of Austrian Federal Railways.

Progress made and lines of further development,

by FREDERIC STRAUSS.
« Modern Transport » Representative for Central and Southern Europe.

Figs. 1 to 10, pp. 633 to 640.

(*Modern Transport.*)

One of the economic results of the partition of the old Austro-Hungarian monarchy was the loss by Austria of her chief sources of coal supply, only about half per cent of the coalfields of the former empire remaining within the borders of the Austria of to-day. Consequently, it became necessary for Austria to import some 65 % of her annual coal requirements (about 9 000 000 tons), a state of affairs which reacted unfavourably upon an already unsatisfactory trade balance. In order, therefore, to relieve the position to some extent, one of the early post-war developments was the building of a number of hydro-electric power stations, while, with the same object in view, the Austrian Federal Railways commenced to electrify their lines. The introduction of railway electrification — quite apart from its effect on the national trade balance — resulted, of course, in increased train speeds, one consequence of which was that the contemplated doubling of the track on the Arlberg section of the Austrian Federal Railways was postponed, while — due to the elimination of soot and smoke with electric working — it became unnecessary to instal an artificial ventilation system in the Arlberg tunnel.

Post-war programme.

No existing steam railways were converted to electric traction before the war, but certain short lengths of line which were originally constructed as electrified railways were in active operation. Of these, the metre-gauge Mödling-Hinterbruhl line, which had been in existence since 1883, can be claimed as the oldest electrically operated railway in Europe; while there was also the St. Pölten-Maria-Zoll line, the normal gauge line from Vienna to the frontier at Hainburg, and the Mittenwaldbahn (Innsbruck-Scharnitz and Griessen-Reutte) line. Following the promulgation by the Austrian Parliament of the laws of 23 July, 1920, and 16 July, 1925, the following lines were authorised for electrification, the dates of completion and lengths of track involved being shown in parenthesis :

Innsbruck-Telfs (22 July 1923—26 km.).
Telfs-Landeck (19 December 1923—46 km.).
Stainach-Irdning-Bad-Aussee (23 April 1924—30 km.).
Bad-Aussee-Attnang-Puchheim (24 July 1924—77 km.).
Landeck-Langen (29 April 1925—39 km.).
Langen-Bludenz (14 May 1925—25 km.).

Bludenz-Feldkirch (6 August 1926—22 km.).
Feldkirch-Buchs (16 December 1926—18 km.).
Feldkirch-Bregenz (17 February 1927—37 km.).
Wörgl-Innsbruck (16 March 1927—60 km.).
Kufstein-Wörgl (9 June 1927—14 km.).
Saalfelden-Wörgl (3 April 1928—80 km.).
Innsbruck-Brennersee (6 October 1928—36 km.).
Salzburg-Schwarzach St. Veit (17 September 1929—67 km.).
Schwarzach St. Veit-Saalfelden (11 March 1930—46 km.).

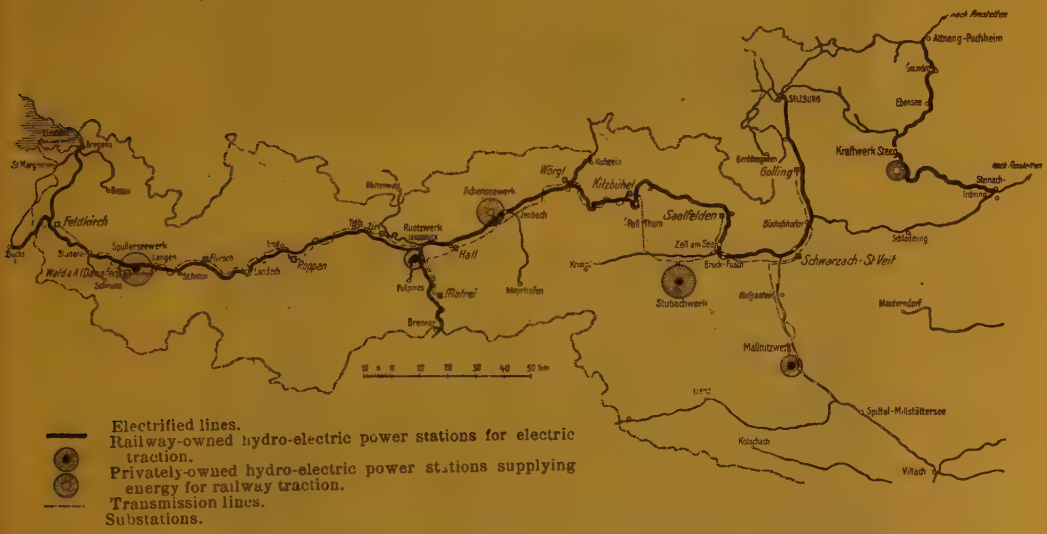


Fig. 1. — Sketch map showing the electrified sections of the Austrian Federal Railways.

The newly-electrified lines, which comprise 623 km. (387 miles [323 km. single track and 300 km. double track]), bring the total length of electrified railways operated by the Austrian Federal Railways up to 844 km. (524 1/2 miles), or 14.5 % of the total railway system of the country, which has a length of 5 860 km. (3 641 miles).

Power supply.

On those sections of the Austrian Federal Railways which were electrified since 1923, single-phase alternating current at 15 000 volts has been adopted, direct current being out of the question in Austria for railway purposes owing to there being practically no power stations in existence for national supply from which the current could be taken. Another important reason for choosing alternating current was the fact that it is in use on the German State Railways, and also on the Swiss Federal Railways; the advantage of uniformity is obvious in the case of junctions at frontier stations with the railway systems of either of these countries. It was only at the Italian frontier station, Brennero, that difficulties were encountered by reason of the difference in the current systems, which was unfortunate in so far as it affected facilities for international traffic. In order to overcome this disability — and after other attempts to find a more simple solution had failed — the Austrian Federal Railways constructed a new station, Brennersee, 1.3 km. (0.8 mile) distant from Brennero, up to which point trains are driven electrically, while from that station to Brennero steam haulage is used.

Fig. 2. — Arrangement of overhead equipment in marshalling yards.

Fig. 3. — Arrangement of overhead equipment on the open track.

Fig. 4. — The substation at Golling.

Power stations.

As the Government had decreed that electrification should not be delayed by reason of the lack of national power supplies, four new power stations were built to supply the necessary energy for the lines of the Austrian Federal Railways west of Salzburg. In addition to these new power stations — the Spullersee, Stubach, Ruetz, and Mallnitz — arrangements were made with two privately-owned power stations for the supply of energy, the Achensee power station for the lines west of Salzburg, and the Steeg power station for the Attnang-Puchheim-Steinach-Irdning section. The Spullersee power station is equipped for dealing with « rush-hour » traffic demands, the Stubach for both « rush hour » and normal traffic, and the Ruetz and Mallnitz power stations for normal traffic demands only. The Spullersee power station draws its energy from the Spullersee, a stretch of water situated about 1 800 m. (5 900 feet) above sea-level, which, dammed by two retaining walls, has a storage capacity of 13 500 000 m³ (2 969 700 000 Br. gallons), while the annual volume of water available from the streams supplying the Spullersee is between 14 000 000 and 17 000 000 m³ (3 079 700 000 and 3 739 600 000 Br. gallons). Taking advantage of an effective fall of 810 m. (2 657 feet), two pipe-lines, each 1 395 m. (3 597 feet) long, conduct the water to the power station. Each pipeline serves two turbines. The equipment in the Spullersee power station includes three direct-impulse turbines, the single-phase generators being so coupled to them that the centre bearing serves for both turbine and generator, each generator set thus having only three bearings. The generators are calculated to give a continuous output of 3 000 k.v.a., but, once the temperature corresponding to this output has been reached, they can supply 5 400 k.v.a for half an hour, or 7 500 k.v.a. for six minutes. The transformers are calculated to give a continuous output of 3 000 k.v.a. but are capable of higher outputs when necessary. The total energy available over a normal working year amounts to 23 500 000 kw.-h.

Stubach, Ruetz and Mallnitz power stations.

The Stubach power station makes use of the water stored in the Tauernmoossee [2 003 m. (6 560 feet) above sea-level], the capacity of this lake being 22 000 000 m³ (4 839 500 000 Br. gallons) and the available fall 526 m. (1 726 feet). The pipe-line, which, together with the conduit, can be thoroughly inspected throughout its entire length, is laid in an inclined gallery, and is 1 750 m. (5 741 feet) long, with an internal diameter of 2.5 m. (8 ft. 2 7/16 in.). The power station is equipped with four motor generator sets, each with a maximum output of 8 000 H.P. The Pelton turbines, as in the other power stations, are arranged as impulse turbines, having horizontal axes, and are capable of 500 r.p.m. The transformer installation at the Stubach power station is of the semi-open-air type, while the energy available over a normal working year is approximately 43 600 000 kw.-h. Meanwhile, the construction of two other power stations — one at a height of about 480 m. (1 575 feet) above sea-level, to produce 65 000 000 kw.-h., and the other at a height of 186.5 m. (612 feet), to supply 42 000 000 kw.-h. — is being considered by the Austrian Federal Railways. The Ruetz power station was built in 1912, on the occasion of the electrification of the Mittenwaldbahn. It originally had two motor generating sets, producing in all 8 000 H.P., but in 1923, when the Arlberg line was electrified, a new set with 8 000 H.P. was added, thus making 16 000 H.P. available. The River Ruetzbach supplies the energy to this station, and the total power available annually is about

42 000 000 kw.-h. The Mallnitz power station utilises the 320-m. (1 050-foot) fall of the River Mallnitz, a pipe-line carrying the water to the works, where two generator sets, each of 5 000 H.P., are installed. The single-phase generators are designed for a continuous output of 4 800 k.v.a., and the annual capacity of the power station at present amounts to 41 600 000 kw.-h. Provision has, however, been made for the installation of two additional generator sets as soon as a demand for more energy is experienced. The Achensee power station, which is owned by the Tyrol Water Power Company, produces 10 600 kw. for the electrified lines from its three-phase installation, which consists of three generator sets. The company has, however, undertaken to raise its annual production of energy for railway purposes to 40 000 000 kw.-h. when so required. The total annual production of energy in the five power stations referred to is about 120 000 000 kw.-h.

Transmission lines.

The five power stations are connected by transmission lines arranged for 55 k.v., the transmission line system being so laid out that parallel working of all stations, as well as a division into individual groups, is made possible. Owing to topographical difficulties, it was impossible to lay out the transmission line system in the conventional manner — as is done in other countries, and in Switzerland in particular. The most important main line section of the Austrian Federal Railways runs from west to east, so that all power stations have to deliver their energy to a transmission line running in the one direction. For this reason, the triangular connection of stations, as is the practice in Germany, was also impossible. So far, however, no difficulties have been experienced in maintaining the supply of energy to the electrified lines west of Salzburg; but it is, unfortunately, a fact that the Spullersee power station is unable to deliver as much energy as had been originally anticipated, which is due to the fact that, the district not being productive of glaciers, long-sustained dry periods react unfavourably upon this particular station. In order to overcome the difficulties which might result from this state of affairs, a fourth generator set is being installed in the Spullersee power station, while, in addition, certain sections of the transmission lines are being re-erected, while in other cases — and notably on the Zirl-Landeck branch of the Arlberg line — the transmission lines are to be of increased gauge. These measures can, however, only be looked upon as meeting the requirements of the immediate future, as the ever-increasing traffic will create the necessity of connecting up the power stations with a second transmission line — in addition to the 55-k.v. line already in use — made to provide a considerably higher voltage transmission, as has already been done in Switzerland. The total length of the 55-k.v. transmission lines is 490 km. (304.5 miles), and, with the exception of two sections (the Schattenberg and Tauern tunnels) where they are laid as single conductor cables, they are on the overhead line system throughout, being equipped as simple contact wires, with two conductors and an earth wire.

Distributing stations.

In the twelve substations the 55-k.v. current is stepped down to 15 k.v. The four older substations — Zirl, Roppen, Fliesch and Danöfen, on the Arlberg line — are constructed as built-in installations, and consist of transformers with artificial cooling equipment. The other eight sub-stations — Golling, Schwarzach, St. Veit, Saalfelden, Kitzbühel, Wörgl, Hall, Matrei and Feldkirch — are constructed as semi-open-air stations and are distinguished by the fact

Fig. 5. — A typical overhead equipment.

Fig. 6. — High-tension transmission line.

Fig. 7. — Hydro-electric power station at Stubach. Inside view.

Fig. 8. — Hydro-electric power station at Stubach. The control room.

that while the 55-k.v. equipment is erected in the open, the 15-k.v. installation, as also the control room, are situated in the built-in portion. There are three transformers installed in the sub-stations, these being of 1 900, 2 100 or 2 400 k.v. continuous output respectively, while provision has been made in certain sub-stations for the erection, if required, of an additional transformer. The mean range of a distributing station is 46.5 km. (28.9 miles), and it is, therefore, possible, should one station be shut down, to feed the section concerned from the neighbouring stations without any great fall in voltage. The sub-stations are not connected in parallel on the 15-k.v. (low voltage) side, so that each sub-station has its own particular section of trolley wire to feed, which mode of supply has the great advantage that faults and breakdowns through short-circuits, etc., are limited to relatively short sections of line. Adequate testing equipment is installed in the sub-stations for the speedy remedying of service interruptions on the trolley wire. The overhead equipment of the Austrian Federal Railways, when first completed, was distinguished by reason of its variations in design, each contractor having introduced a different system. From the point of view of service maintenance and upkeep of the trolley wires themselves, this state of things was unable to continue, and, accordingly, in 1925, steps were taken to secure uniformity.

Service interruptions.

The interruptions in the electrified service originating in the trolley wires are mainly due to flashing-over, which occurs on sections where, as a result of defective locomotives, steam traction is still used to some extent, thus also causing the insulators to be choked with soot. Breakdowns caused by short-circuiting on the locomotives are few and far between, but other interruptions in the services are due to short-circuits caused by birds and animals. The number of breakdowns on all lines equipped for electric traction amounted in 1929 to 361 as against 434 in 1928, which is a gratifying reduction in view of the fact that the length of electrically-operated lines has increased in the same period from 730 to 790 km. (454 to 490 miles). The remedying of defects in the trolley wires during the first few years of operation was partcularly difficult owing to the different types of wire used, all of which necessitated carrying very large stocks of spare parts. However, the Austrian Federal Railways are now endeavouring, by the speedy adoption of a uniform trolley wire system, to standardise the stocks, thus effecting a considerable saving in both material and money.

Rolling stock.

With the introduction of electric traction there arose immediately the necessity for the erection on an electric locomotive shed of ample proportions. Meanwhile, however, there were considerable difficulties in the way of the introduction of electric locomotives, for the permanent way, due to the effects of the war, was in a bad condition on practically all the lines destined for electrification. Moreover, although the permissible axle-load was increased from 14.5 to 16.5 tons, there were also difficulties in deciding upon the most suitable type of locomotive owing to the numerous and narrow bends, which meant that the locomotive had to have as short a wheelbase as possible, while, on the other hand, the stiff gradients — up to 31 in 1 000 — were bound to impose a very severe tax on the power. These difficulties of construction account to a great extent for the multiplicity of types — there are altogether thirteen — of electric locomotive which have been introduced into service, and up to the present the Aus-

trian Federal Railways have had insufficient experience of them to enable them to decide upon any particular form of construction as standard. Efforts are now being made, however, to standardise as far as possible new individual parts, a start having been made, for instance, with instruments, auxiliary apparatus and, just recently, current-collectors and oil circuit breakers. For their express passenger services the Austrian Federal Railways employ sixteen 2-6 + 6-2 type electric locomotives, twenty of 2-6-2 type, and sixteen (five more on order) of the 0-4 + 4-0 type, while thirty-eight express locomotives of the 2-8-2 wheel arrangement are also in service. In addition, eight 0-6 + 6-0 passenger locomotives are also employed. For goods services there are fifty-two electric locomotives of 0-10-0 type and one of 2-10-2 type, while for shunting and goods services fourteen 0-8-0 type locomotives are used.

Express and goods locomotives.

The 2-8-2 type express locomotives have individual axle-drive through articulated coupling and vertical motors, each uncoupled axle being mounted with the neighbouring driving axle on a bogie. Each driving axle is driven by a double motor arranged in tandem. The control of the locomotive is effected by compressed-air circuit breakers which are electrically interlocked. Two driver's cabs are fitted, one at each end. So far as braking arrangements are concerned, this type of locomotive, like all others used in Austria, is fitted with vacuum and compressed air brakes, this being due to the fact that much of the traffic in Austria is of an international character, which necessitates the rolling stock being equipped with both systems. As a result of the shortage in electric locomotives, an exceedingly large amount of work is done by the available stock, it being estimated, for instance, that the 2-8-2 type locomotives only return to the shed for a thorough examination after they have covered some 4 000 to 6 000 km. (2 500 to 3 750 miles), which they do in almost uninterrupted running and with standing periods of only a few hours at a time. Generally speaking, the average distance covered per month by the 2-8-2 type locomotives is from 10 000 to 16 000 km. (6 200 to 9 950 miles), and after they have completed from 150 000 to 200 000 km. (93 000 to 124 000 miles) they undergo a general overhaul. When it is remembered that the different types of steam locomotive had to undergo the same treatment after they had covered some 80 000 km. (49 700 miles) or so on the very mountainous sections which are now electrically operated, it would seem to indicate that electric locomotives do not need overhauling until they have covered more than twice the distance of the steam locomotives.

With regard to conditions on the electrified lines west of Salzburg, it may be said that the unfavourable track conditions — especially the long and difficult mountain sections of Saalfelden-Wörgl, Innsbruck-Brennersee, Landeck-Bludenz — impose very serious restrictions on speed. In spite of these disabilities, it is possible to negotiate the 25-km. (15.5-mile) section from Bludenz to Langen, with a mean gradient of 31 in 1 000, in 36 minutes, which journey would have occupied 71 minutes by steam-hauled train. On these gradients it is, in most cases, imperative, in addition to double-heading, to employ banking engines, this being obligatory under regulations internationally agreed upon in the case of traction machinery of light construction. It is, it may be remarked in passing, much to be regretted that this subject, which was introduced by Mr. Bals, general inspector of the Rumanian State Railways, at the eleventh International Railway Congress at Madrid, was not considered more fully when the subject of main line electric locomotives was being discussed, as dif-

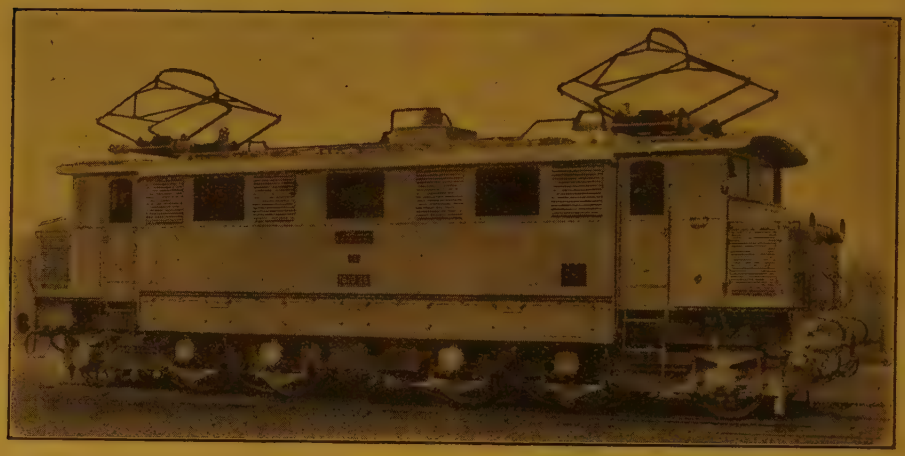


Fig. 9. — A 2-8-2 type express passenger locomotive, Austrian Federal Railways.

Fig. 10. — Electric locomotive (0-10-0 type) for heavy goods traffic, Austrian Federal Railways.

ficulties have already arisen in actual practice with electric drive.

Maintenance and repair shops.

For the maintenance and repair of the electric locomotives, special engine shops and service depots were constructed, one at Attnang-Puchheim, for locomotives operating on the Attnang-Puchheim - Stainach - Irdning line and others at Salzburg, Innsbruck and Bludenz for locomotives employed on the electrified system west of Salzburg. At

these shops the electric locomotives are kept in running order and minor repairs effected during the construction of the new locomotive-overhaul shops at Linz. One of the most up-to-date engine shops is at Innsbruck-Westbahnhof, where there are employed, including the locomotive crews, 700 workmen.

Further extensions.

As, in the course of seven year's electrified service, the advantages of this type of traction have proved themselves to be of inestimable benefit, the electrification of further important main line sections is being considered by the Austrian Federal Railways as a continuation of the first electrification programme, which was concluded by the electrification of the Schwarzach St. Veit-Saafelden section. In this connection it is obvious that the electrification of the Salzburg-Attnang Puchheim main line should be carried out first and foremost, with a view to organising the electrified services on a continuous traffic basis. This 70-km. (43.5-miles) section forms part of the Salzburg-Vienna main line, and, as Salzburg and Attnang-Puchheim are both situated at a height of 400 m. (1 312 feet) above sea-level, and the highest point of this section, Ederbauer Station, is 600 m. (1 970 feet) high, it has on both sides a difference in elevation of about 200 m. (656 feet) to surmount, with gradients up to 11 in 1 000. The electrification of this section would connect Salzburg and Attnang Puchheim stations — which are already arranged for electrified services — and also the electrical workshops at Attnang Puchheim station, and the electrically-operated (107.5 km. = 66.8 miles) Attnang Puchheim-Stainach-Irdning section, with the western electrified main line system, while it has the further advantage of being better able to make use of the locomotive stock of the western main line, which, in the absence of night traffic, and on account of the long intervals between trains, is not utilised to the best advantage. The necessary energy for hauling trains on the Salzburg-Attnang Puchheim line could easily be supplied after slight extensions to the four railway-owned power stations and by the Achensee power station, as these can yield about 20 000 000 kw.-h. annually. Besides this, the Steeg power station, which at present only feeds the Attnang Puchheim-Stainach-Irdning line, could be brought in to supply energy for this line. The building of a special power station could, therefore be obviated, the only necessary addition being a distributing station at Ederbauer. Naturally, transmission lines of 110-k.v. capacity would have to be erected from the Stubach power station to the east. On the subject of the further electrification of the Attnang Puchheim-Vienna line, opinions are divided. In any case, the further electrification activities of the Austrian Federal Railways will depend on whether or not a foreign loan can be raised at the lowest posible rate of interest; for it has been proved, both in Germany and Switzerland, that the electrification of a railway can only be made to pay during the time required for the amortisation of the capital when the interest on the capital taken up ranges somewhere between 4 and 6 %.

An aid to international traffic.

At comparatively small constructional cost, the electrification of the 80.9-km. (51-mile) Tauernbahn Schwarzach St. Veit-Spittal section could be carried out. The electrification of this main line, which has an average gradient of 25 in 1 000 and 16 tunnels in a total length of 14.6 km. (9.1 miles), would be greatly welcomed from a service point of view. The steep inclines on both sides of the Tauern tunnel demand greater consumption of energy, and would, therefore, if electrical haul-

age were adopted, contribute to economy in coal. This demand could, however, be met by the Mallnitz power station, which is situated close to the Tauernbahn, over long-distance wires, without great losses of current. From the point of view of international traffic, electrification of the Salzburg-Vienna and Vienna-Hegyeshalom (Hungarian frontier) lines would also be very desirable, as the Hungarian State Railways are now electrifying the section between Hegyeshalom and Budapest. If these sections of line were electrified it would be possible to take not only the international expresses from Geneva or Basle to Budapest over a distance of 1 433 km. or 1 233 km. (890 or 765 miles) respectively, but also to deliver transit traffic electrically, thus creating in the heart of Europe an electrically-driven universal traffic route.

[625. 258 (.44) & 656 254 (44)]

Slipper-brakes in shunting yards.

Figs. 1 to 5, pp. 644 to 648.

(*The Railway Engineer.*)

Considerable attention has of late been paid to the question of the provision of retarders for checking the speed of wagons after they have left the hump. This is particularly the case since the introduction of retarders at the Whitemoor Yard, March, of the London & North Eastern Railway (1). Such an equipment brings with it many economies, in that it reduces the number of brakesmen, minimises the risk of damage to wagons or their contents when shunted against other wagons, and allows for wagons to be shunted with a greater speed when passing down and off the hump and for a less interval between each wagon.

The car retarders now being much used in the United States and as exemplified in the wagon retarders at Whitemoor, require machinery, and, consequently, power, for their operation, whilst all the designs provide for only one braking. In the apparatus now about to be described all the power required is 220 volts to drive an electrical motor winch combination, and there are three series of braking. These latter are to give, according to the weight of the wagon — which may be as much as 30 tons — together with its speed and the distance it has to travel, only one brake application, or two or, if necessary, three, brakings. Just as in the mechanical braking schemes, the braking can be for a long or a short period.

The arrangement in question has been in operation for seven years at the La Délivrance Yard, Lille, of the Northern Railway of France; since 1925 at Blainville on the Eastern of France and since 1926 at Metz-Sablon on the Alsace-Lorraine System (2). Plans are now under consideration for an installation for the Eastern Railway yards at Conflans-Jarny and at Is-sur-Tille, also for another on the Northern at Le Bourget.

The method of operating the slipper is the invention of Mr. Deloison, chief of the locomotive running shed at Lille, and Mr. Deyon, his foreman. The British agents and manufacturers are Tyer & Co. Ltd., of Dalston, and to the gentlemen named and to that firm the writer owes a recent opportunity of seeing the apparatus in work at Lille; the present article is based on the experience there.

The yard at La Délivrance has 10 reception lines which converge, at its southern end, into the four roads seen on the extreme right in the accompanying plan, figure 1, through which the wagons are shunted by gravity, by means of a 1 in 55 falling gradient, into 37 sorting sidings. These sidings are laid on the level and the sorted wagons are drawn out at the other end and propelled into the departure roads, which are 23 in number, and, parallel on the east, the sorting sidings. The movements between the reception lines and the sorting sidings are controlled by cabin No. 4,

(1) See *Bulletin of the Railway Congress* for March 1931, p. 216.

(2) See *Bulletin of the Railway Congress* for December 1929, pp. 3078 *et seq.*

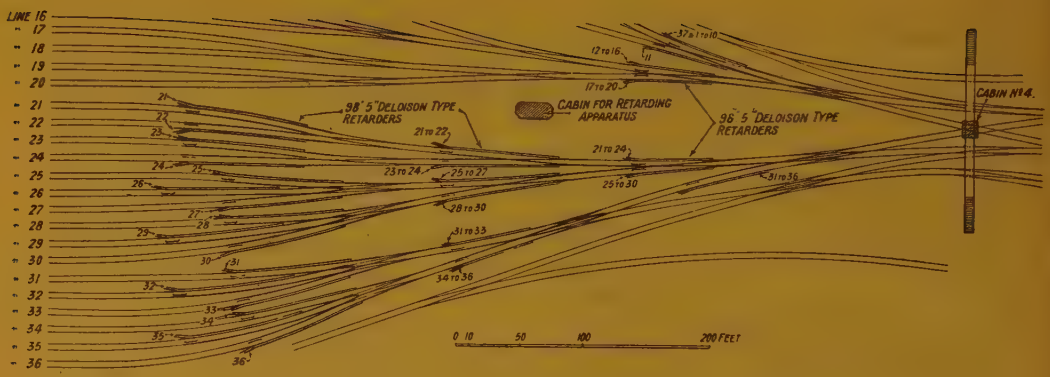


Fig. 1. — Plan of portion of yard, showing positions of slipper-brakes.

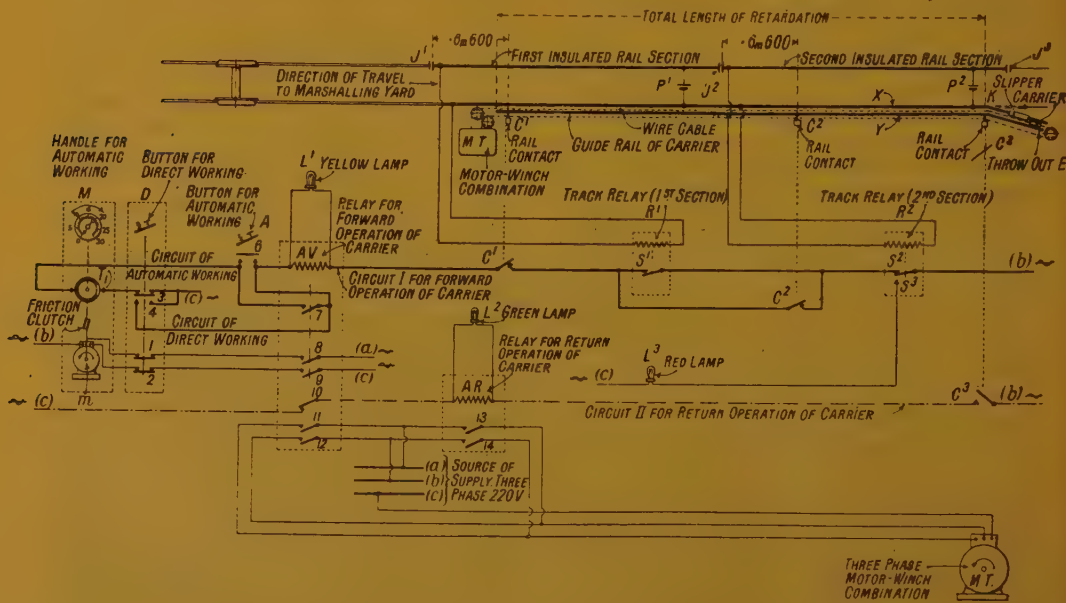

TOTAL LENGTH OF RETARDATION
FIRST INSULATED RAIL SECTION
SECOND INSULATED RAIL SECTION
DIRECTION OF TRAVEL TO MARSHALLING YARD
SLIPPER CARRIER
WIRE CABLE GUIDE RAIL OF CARRIER
RAIL CONTACT
MOTOR-WINCH COMBINATION
TRACK RELAY (1ST SECTION)
TRACK RELAY (2ND SECTION)
THROW OUT E
HANDLE FOR AUTOMATIC WORKING
BUTTON FOR DIRECT WORKING
BUTTON FOR AUTOMATIC WORKING
L' YELLOW LAMP
RELAY FOR FORWARD OPERATION OF CARRIER
CIRCUIT OF AUTOMATIC WORKING
CIRCUIT I FOR FORWARD OPERATION OF CARRIER
FRICTION CLUTCH
CIRCUIT OF DIRECT WORKING
L² GREEN LAMP
RELAY FOR RETURN OPERATION OF CARRIER
L³ RED LAMP
CIRCUIT II FOR RETURN OPERATION OF CARRIER
(a) (b) (c) SOURCE OF SUPPLY THREE PHASE 220V
THREE PHASE MOTOR-WINCH COMBINATION

Fig. 2. — Diagram showing original electrical control system for slipper-brakes.

which, as seen in figure 1 and figure 3, is fixed over the four converging roads. It contains an Aster all-electric locking frame of 78 levers. The braking is exercised from an independent control building — seen in the centre of figure 3 — as the signal-box was already in existence and there was not room therein to accommodate the control mechanism. In future installations, however, both operations will be in the same cabin.

The braking is done by means of a slipper which travels on the running rail marked X in the diagram of the electrical

connections, figure 2. The slipper is normally in the throw-out or pocket E, as also seen in figure 3, and a little further inside the pocket is a carrier which is attached to a wire cable and operated by the motor winch combination MT, whereby the carrier is brought out of the pocket, driving the slipper before it. As will now be explained, the controller brings the slipper sufficiently far forward to suit the speed of the oncoming wagon and the distance it has to travel along the sorting sidings. In the control tower are three control boards, figure 4, with a series of circular discs.

Following now the electrical connections in figure 2, the disc is seen at M. It has a knob in the centre and a pointer on its dial and figures of distances in metres. This is for the purpose of determining the distances the slipper shall travel from the throw-out to meet an approaching wagon. That is the first thing the controller does, and he thereby turns the switch T 1 to the position representing the required distance. On pressing the button A on the left side of the disc the circuit 1 is now closed through T 1, contact 6, rail contact C 1, track relay contact S 1, rail contact C 2, and track relay contact S 2.

The relay A V is now energised, and the result is that contact 7 is closed, and completes the circuit I, when contact 6 is broken on the man releasing button A; contacts 8 and 9 are closed and complete the circuit to motor *m*, which is coupled by a friction clutch to the switch T 1; contacts 11 and 12 are closed so that the motor M T revolves and draws the carrier with the slipper in advance of it out of the throw-out E. The motor *m* revolves in synchronism with the motor M T and brings back the pointer of the disc M, and as soon as the pointer reaches zero the switch T 1 breaks contact with the circuit I and the travel of the slipper stops — at the distance selected by the man.

Relay A V will now be de-energised and contacts 7, 8, 9 broken. Contact 10 will, however, be joined, and so circuit II is closed. Relay A R is now energised and contacts 13 and 14 closed; thereby the two phases of the working circuit of motor M T are reversed and the motor revolves in the opposite direction so that the carriage is taken back into the throw-out E and the slipper left on the rail to receive the wheel of the oncoming wagon. The wheel rides on the slipper, forcing it along with the wagon until the slipper reaches the cut K, when it passes into the throw-out. The carriage, in its travel, joins up contact C2, and on arriving at the throw-out cuts the circuits II at contact C3. The relay A R thus becomes de-energised and so cuts out the circuit of M T, which stops.

When, as in the daytime, the men in the control tower readily can see the slipper, they do not trouble to set the disc M, but employ what is known as direct working. In that event the man presses the button D on the right side of the disc, and thereby contacts 1, 2, 3 are broken and 4 closed. Circuit I is now made through rail contact C 1, track relay contact S 1, rail contact C 2 and track relay contact S 2, and relay A V energised. The operation of the carriage and slipper is then as before, except that, if the man has not released button D, current to the motor is broken when the carriage reaches rail contact C 1. When that is done, also when the button is released, the motor M T is reversed, and the carriage returned to the throw-out, leaving the slipper on the running rail.

Each disc is provided with a red, a green, and a yellow lamp. The yellow light L 1 is switched in when the circuit is completed for the forward movement of the carriage, and is switched out as soon as the carriage starts to return; the green light L 2 is then switched in, and it is switched out as soon as the carriage actuates rail contact C3. Should a wagon be standing on the track circuit J2, J3, the red lamp L3 is illuminated.

It will be observed that there are two sections of track circuit P1 and P2, the

outer ends of which are the joints J1, J3, and which are divided at joint J2. The purpose of these is two-fold; firstly, to stop the carriage from leaving the throw-out if a wagon is on the track circuit P2, and, secondly, to stop and reverse the carriage at rail contact C2 if a wagon is on track circuit P1.

A great improvement has now been made in the operation of the carriage. In the arrangement above described the operator could move the carriage, with its slipper, forward, to meet an advancing wagon, as far as is considered desirable, but, should he find that he had sent it farther than was necessary, and so was giving a longer braking distance than conditions required, he could not draw it back. The improvement now made retains the carriage, and its slipper, under the control of the operator, to move as he thinks fit until the wheel actually is on the slipper.

Figure 5 illustrates the new scheme. Therein the carriage is 1, and the stop of the slipper which the wheel strikes is 2. The running rail and the guide rail, which are respectively X and Y in figure 2, are 3 and 4 in figure 5. The base of the slipper is 6 and the endless cable is 7. The base 6 has a bore 14 in which is the piston 15 which grips the cable 7, and the upper end of its rod 16 is connected to a lever 17 working on a centre pin 18, fixed transversely on the shoe 19 of the slipper. At the other end of lever 17 is the treadle 20. The spring 21 presses the piston 15 against the cable which works between the roller guides 23 on the plate 22, which is the bottom of the base 6. Normally, then, the carriage grips the cable and moves to and fro as worked by the motor M T in figure 2.

From the foregoing explanation it will be appreciated that, when the wheel of a wagon strikes the treadle 20; the rod 16 is raised and piston 15 loses its grip of the cable 7. The wagon will push the carriage and slipper before it until the cut K in figure 2 is reached; then the wagon will continue along the running rail and the carriage and slipper enter the throw-out. As soon as the wagon leaves the slipper, treadle 20 is released, and the spring 21 will cause the piston 15 again to grip the cable. In order to ensure that the slipper goes fully inside the throw-out and is not left foul, there is provided an electrical contact at the cut K, which causes the motor to be energised so that the slipper is drawn clear. A second contact farther inside cuts off the motor when the slipper is fully in the throw-out.

Added to the great benefit the improvement has brought that the slipper can now be moved backwards, as well as forwards, at the will of the controller, there is satisfaction in the fact that the track circuits, with their contacts, relays, etc., are dispensed with — an economy in first cost and in maintenance and renewal.

An interesting feature is that bogie wagons can have two brake applications. After the slipper has been passed into the throw-out by the leading wheel of the first bogie, it can be brought forward in time for an application to the second bogie.

Inspection of the rails at the retarding points shows that the heads are not worn, nor have there been any complaints as to flats on the wheels. A shoe will handle 3 000 wagons before the nose or cushion needs replacement. Those parts are then cut off and a new shoe or cushion welded on by the oxy-acetylene process. A supply of slippers lies near the retarders ready for use when occasion arises. At La Délivrance yard 4 200 wagons are shunted into the sorting sidings during the 24 hours.

It should be explained, in conclusion, that, although the Deloison system, as used at Lille, is applied to shunting by gravity, it is equally adapted to hump shunting. Experience at Metz-Sablon, which is a hump yard, shows further that the higher speed resulting from hump shunting can readily be met by the Deloison arrangement; in fact, the gradient of the hump there is 1 in 16, and there-

Fig. 3. — General view, showing electrically controlled slipper and special rail guide.

Fig. 4. — View in control cabin, showing operating apparatus.

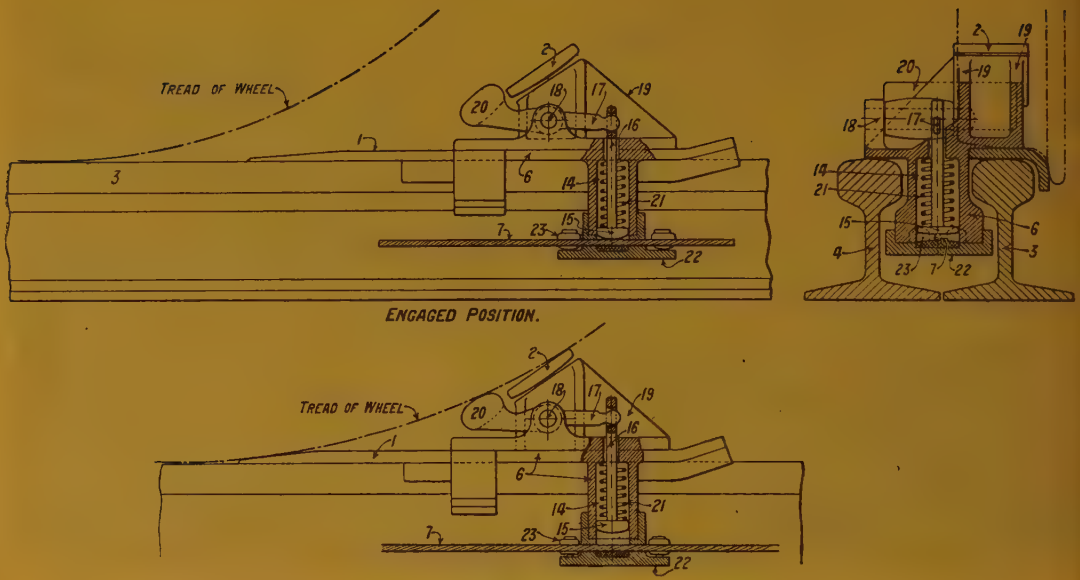


Fig. 5. — Details of improved slipper.

fore is steeper than the 1 in 18 which has been adopted in the case of Whitemoor.

It is not our intention to make any comparison between the braking by means of an electrically-operated slipper and by the use of other retarders. It is, however, only fair to say that the Deloison system :

1. is simple;

2. needs no hydraulic or penumatic power;

3. there is no wear on the braking mechanism and a slipper can quickly be replaced;

4. more than one braking can be given to a wagon;

5. there is no difficulty with wheels of the Mansell type, which have bolts and nuts on the face of the tyre;

6. bogie wagons can have a second check at the same retarder;

7. the only possible cause of failure would be in the electrical current, and that can at once be effectively met by hand-placing of the slippers on the rail; moreover, electrical failures usually are of short duration;

8. as shown in the severe weather of 2 years ago, the working is not affected by snow, frost or similar conditions.

MISCELLANEOUS INFORMATION.

[625. 143.5]

1. — Transverse fissures in steel rails,

By a Correspondent.

(*The Railway Engineer.*)

On 1 December 1929, a passenger train running over the Norfolk Division of the Pennsylvania Railroad was partially derailed at Onley, Va., resulting in the death of eight passengers and one employee, as well as injuries to 32 others. The train was travelling at an estimated speed of 50 m.p.h., over a track laid with 100-lb. flat bottomed rails, and well maintained; derailment began with the third coach from the engine, and this and the remaining seven cars were all thrown off the track. It is clear that the cause of derailment was a broken rail, and that the cause of breakage was a transverse fissure, spreading internally over more than two-thirds of the cross-sectional area of the rail-head. Apart from the fissure which caused derailment, several other transverse fissures were found in the rail that failed. The rail had been in the track all but 13 years. The report to the Interstate Commerce Commission on the accident, by the Director of the Bureau of Safety, offers an extremely interesting study of the question of transverse fissures in rails.

There is no question that in America this defect is a serious menace. Chiefly by the use of the Sperry detector car which, when run over a length of track makes it possible, by electrical means, to discover these dangerous flaws, in 14 months 257 fissures were discovered in the Pennsylvania tracks alone, in rails ranging chiefly between 100 lb. and 130 lb. per yard weight. The age of the rails concerned varied from three months to 40 years, but 26 were less than a year old. In these 257 rails 210 different casts of steel were represented, so that the trouble is of a general character, rather than confined to a few casts of extreme chemical analysis. One cast was responsible for 7 fissures, one for 5 and one for 4, but no others for more than 3 each. In one 19-mile section of track, between Lewistown and Harrisburg, 31 fissures were discovered, all in 130-lb. rails with an average life of 2 2/3 years, 16 of these being located in one single mile of line. Another excursion by the Sperry detector car over the Delaware and Hudson Railroad resulted in the discovery of 62 transverse fissures in 90-lb. rails during an itinerary lasting one month, nearly one-half of the flaws being in rails less than one year old. It is also a disturbing feature that the number of these transverse fissures is constantly on the increase. Railroads operating within the State of New York are required to report to the Public Service Commission the number of such fissures occurring within the limits of their jurisdiction. Eight of the chief lines reported an aggregate of 395 fissures in 1922. 367 in 1923, 367 in 1924, 381 in 1925, 531 in 1926, 489 in 1927 and 542 in 1928. From 1923 to 1928 inclusive the Pennsylvania figures alone were 135, 144, 165, 269, 254 and 301 per annum. An important external consideration affecting the rapid increases since 1925 has been the general speeding-up of freight traffic, which has increased the load impact effect on the rails of main line tracks, and is held to be in part responsible for fissural development.

The transverse fissure is a defect which is found in the interior of the rail-head, at right angles to the length of the rail. It is, as its name implies, a fissure or crack in the metal, which gradually increases in size, often from a small nucleus, until it extends over one-half or more of the cross-sectional area of the head, under the constant impact of the traffic. Fracture discloses a corona of silvery and attractive appearance, which rapidly darkens by exposure to the atmosphere. These fissures normally occur in rails to which no exception can be taken on the grounds of chemical composition, structure or

physical properties. The results of such investigations as have already been made, however, point to the conclusion that the transverse fissure comes into existence, in the first instance, during cooling of the rail after rolling. At a suitably high temperature, when the metal is plastic, steel may be moulded into different shapes, by forging or rolling, with a minimum of effect on its final properties. But between this plastic state and the rigid condition that the metal reaches when cold, there is a brief interval which marks a condition of peculiar sensitiveness. According to the rate at which the steel cools through this critical zone, so profound differences in result may follow. It may reach a state of repose free from internal strains, or, on the other hand, it may be charged with such conflicting strains that rupture will ensue. The transverse fissure is a rupture of this character, and, assisted by internal strains still present in the steel after this rupture has taken place, under the running of trains it tends to spread until a complete fracture of the rail takes place.

American track conditions.

In regard to the future, the author of this American report takes a gloomy view. The question is immediately presented, he says, as to whether service conditions of to-day have not practically destroyed the residual elements of safety in all grades of steel. Proper investigations of the rail problem during the period that the weight of equipment and the speed of trains has been unceasingly on the increase has been neglected. For a rail of superior endurance the quest goes on unceasingly. Different steels have been tried, with a view to reducing the transverse fissure trouble, but in vain; in fact, complete elimination of these flaws seems an impossibility. No relief is to be expected from any amelioration of the conditions under which the rails are used; indeed, as the writer of the report says, the very essence of modern railroad operating practice is an obstacle which cannot be overcome. He dismisses the suggestion of heat treatments as being a remedy worse than the disease, in the uncertain and possibly dangerous effects that they are likely to have on the higher grades of rail steel in use in America. By higher grades, of course, are meant steels very high in carbon content.

Transverse fissures in rails are not unknown in Great Britain, but, so far from occurring by the hundred, they are still a comparatively rare defect in this country, and no derailment or other casualty has as yet been attributed to their presence in British rails. The reason for this difference is the addiction of American rail-users to extremely high percentages of carbon, increasing out of all proportion the sensitiveness of the steel during cooling, to which reference was made in this report. Analysis of the rail which formed the subject of the report gave a carbon content of 0.75 % , though manganese was only 0.74 %, and phosphorus and sulphur were negligibly low. In normal British practice no higher carbon content than 0.65 % is permitted, efforts to introduce high-carbon low-phosphorus rails, of the so-called « plough » steel quality, with over 0.70 % carbon, having met with little success here.

As the report indicates, the Americans are in a quandary. With axle-loads exceeding 30 tons (as compared with the British maximum of 20 to 22 ½ tons), passenger train-loadings of 1 000 to 1 200 tons, and freight trains of 3 000 tons and upwards running at average speeds of 40 to 45 m.p.h., the punishment suffered by the rails is such that, unless a very hard quality of steel is used, they fail by « mashing » — that is, crushing or rolling over the rail-head. Again, it is to provide adequate resistance to bending in the vertical plane that American rail sections have been increased in cross-sectional area until the 130-lb. per yard rail is now in common use. But this introduces another weakness, as in the reduction of the ingot at the rolling-mill to the larger cross-section, less work is done upon the steel in rolling, so that the coarser internal structure of the rail-head is less fitted than previously to withstand abrasive wear; in this respect also, unless a very hard steel is employed, the life of the rail under American conditions is likely to be abnormally short. Another consideration is that,

multi-cylinder locomotive propulsion still being somewhat of a rarity on American railroads, to heavy axle-loadings, there is added the harmful effect of excessive « hammer-blow », at high speeds, from the heavy rotating parts used on the locomotives in conjunction with two cylinders of very large dimensions; this is a potent assistance to the development, from a small nucleus, of a transverse fissure, and to the ultimate fracture of the flawed rail.

Some possible remedies.

It is probable that a more widespread recognition of the toughening properties of manganese in the composition of the rail would help towards a solution of the problem, but not unless carbon content is reduced below the excessive figure of 0.70 to 0.75 %, which is almost universally accepted in America. An editorial article in the June 1930 issue of *The Railway Engineer* referred to the growing popularity in the United States and Canada of the « medium-manganese », rail, of which large tonnages are now in use, but in which very high carbon percentages, up to 0.70 %, are still associated with manganese contents of between 1.20 and 1.70 %. Were the carbon reduced to about 0.50 to 0.55 %, the wear-resisting properties of the manganese might be utilised to the full without the attendant risk of transverse fissures, as a steel of this character is known to be considerably less « sensitive » in character when cooling from its plastic to its rigid condition than a steel containing over 0.70 % carbon. The matter of heat treatment also, provided that it is appropriate to the chemical composition of the rail treated, is not of the negligible value indicated in this American report. Exhaustive experiments which have been made in this country have proved that internal cooling strains in rails may be reduced materially by soaking at a temperature of between 350 and 400° C. — the range of maximum sensitivity — immediately after rolling, for about 30 minutes. This treatment is now applied, with very beneficial results, to rails which have been heat-treated by the Sandberg sorbitic process at the works of the Cargo Fleet Iron Co., Ltd., of Middlesbrough, and although under test transverse fissures have been discovered in rails rolled of high carbon compositions in this country, as yet no such fissures have been found in rails which have been subjected to this soaking after rolling, even when they have been sorbitised. It is significant that similar soaking plants are now being laid down at certain well-known American rolling-mills.

The serious question of the transverse fissure is now to receive more detailed investigation. After having been notified up to the end of January, 1929, of the enormous total of 35 797 transverse fissures in rails in the United States, with an annual increase exceeding 5 000, the American Railway Engineering Association has now asked for, and is to obtain, an appropriation of money for conducting exhaustive research on the subject. Presumably the composition of rail steel and the method of manufacture of rails in rolling mills will come within the terms of reference of the committee to be appointed. Such research is badly overdue, not only in America, but in this country, in view of the enormous annual outlay of the railways on rail renewals. It is to be hoped that the findings of this committee will be made public, as they should be of vital interest to railway engineers throughout the world.

[656. 253 '.42)]

2. — Automatic train control on Great Western of England.

Figs. 1 to 3, pp. 652 to 654.

(From *Railway Signaling.*)

The Great Western Railway of England has adopted plans for the installation of its automatic train control system throughout hundreds of miles of its lines. The present installation from London to Oxford, High Wycomb and other points, aggregating 372 miles

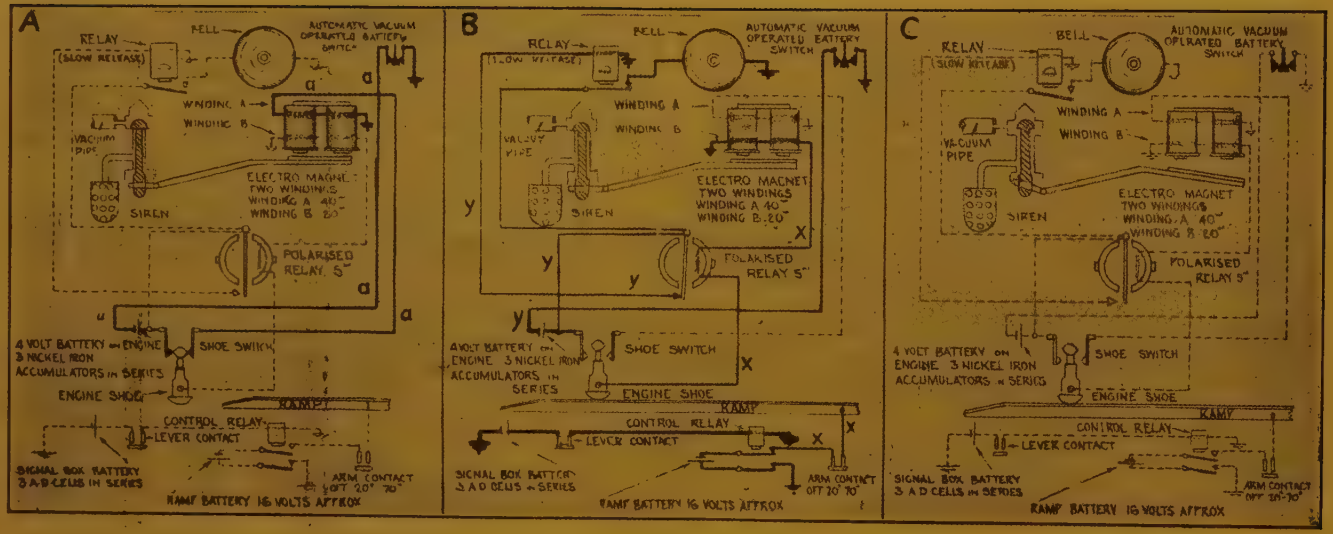


Fig. 1. — Engine and wayside control circuits.

of track, is being expanded to a total of 2 130 miles of track. Locomotives, including both passenger and freight, will be equiped to the number of 2 334. The estimated total cost of this enterprise equals about $1 000 000, and it is expected to complete the work within one year.

Contracts for the equipment on the locomotives have been let to the Westinghouse Brake & Saxby Signal Company, the British Power Railway Signal Company, and the General Railway Signal Company. The work of installation, including the manufacture and installation of the ramps, will be done by the railway company's forces.

This is a ramp system, with intermittent mechanical and electrical contact. It was introduced as a cab signal (without brake-setting apparatus) about 24 years ago on the Fairford branch, and its use has been gradually extended. The mechanical and electrical features of the system, as in use to-day, are described in the attached drawings.

The system, as here described, is operated in connection with manual block signals, and the brake is the automatic vacuum system. The control of the ramp to give a *Proceed* or a *Caution* signal is in the hands of the signalman, who opens or closes an electrical contact when he moves his distant signal lever, and

Fig. 2. — Locomotive cab.

the application of the brakes on the train is effected by admitting air to the normally exhausted vacuum brake pipe. The *Caution* indication is a siren in the cab, the admission of air to the brake pipe through the siren causing the sound. The *Proceed* indication is a short ring of a bell. The ramp, a steel bar, inverted T shape, fixed on the roadway, is 44 ft. 3 in. long. It is supported on a timber centrally located between the rails and is staggered 3 inches to the center line; that is to say, the entering end of the ramp is 1 ½ inches to the right of the center and the leaving end is 1 ½ inches to the left. The top of the ramp at its highest point is 3 ½ inches above the top of the rail.

The electrical connections will be understood from the diagrams A, B, and C; the first one, A, shows the normal condition; B, *Proceed*, and C, *Proceed with caution*. Normally, the electric wire from the cabin to the ramp is dead. The placing of the signal lever to the *Proceed* position energizes circuit x, diagram B, and the bell, indicating *Proceed*, is energized by circuit y, which is closed by the action of circuit x on the polarized relay. This circuit also energizes winding *B* of the electro-magnet, holding the brakes off.

The contact shoe which is supported on the frame of the locomotive beneath the cab, is held in position by gravity, assisted by a powerful spring. It is raised vertically one inch whenever a ramp is passed over, and this movement opens the switch, which is a

part of the shoe. This switch, closed, as in fig. A, before reaching the ramp, completes circuit a and, through winding A of the magnet, prevents the brake valve from opening. The opening of the switch on reaching the ramp causes the admission of air through the siren and the brake valve to the train pipe, sounding the siren and applying the brakes. This happens when an engine passes

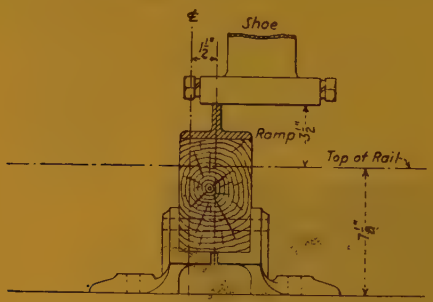


Fig. 3. — The ramp on a curve.

over an unelectrified ramp. The engineman, by acknowledging the warning given by the sound, can silence the siren and forestall the application of the brakes. This he does by raising a handle (shown on the outside of the box which is fixed at the engineman's side in the cab) and his act prevents the dropping of the armature of the magnet.

When the engine shoe is in its lowest position, and its switch is closed, a current of 100 m. a. flows from the 4-volt storage battery through the 40-ohm winding A of the electromagnet. This holds up the armature. The armature is coupled to a hinged lever, the opposite end of which is inserted in the stem of the brake valve. When the armature drops away, the lever end lifts and causes the brake valve to open; air is drawn through the siren, which is sounded, and the vacuum is partially destroyed.

When the ramp is electrified — meaning line clear — the contact shoe is lifted as before, but the current to the 40-ohm winding of the magnet is open at the shoe switch and a current of about 500 m. a. is picked up momentarily from the ramp. Circuit x is then energized through the 5-ohm winding of the polarized relay and the 20-ohm winding of the electro-magnet. Thus, though the shoe is lifted, the air valve is not opened, the magnetic field being maintained. The polarized relay contact closes circuit y, the effect of which is to ring the bell for one or two seconds.

When a locomotive is laid up for the night or for any time over one-half hour, the automatic cutout, shown in the upper right-hand corner of the drawing, is operated by the vacuum brake system, opening the circuit of the engine battery, thus economizing battery power. When the vacuum is restored by the engineman, prior to releasing the brakes, the cutout pulls up and again energizes the brake magnet. The engineman then silences the siren (which is revived as soon as the vacuum is restored) by lifting the resetting lever.

NEW BOOKS AND PUBLICATIONS.

[385. 6 (43]

WOLF (P.). Geheimer Regierungsrat, Direktor der Deutschen Reichsbahn Gesellschaft. — **Die Deutsche Reichsbahn und ihre Beziehungen zu ausländischen Eisenbahnen (The German Railways and their relations with the railways of other countries).** — One volume, DIN A-5 (8 1/4 × 6 inches) of 152 pages. — Berlin W. 9, published by the « Verkehrswissenschaftliche Lehrmittelgesellschaft m. b. H. bei der Deutschen Reichsbahn », 6, Voss-Strasse. (Price : 9 *Rm.*)

For a long time, one might almost say since their beginnings, the sphere of activity of railways has been extended to include transport between different countries. International relations soon made necessary a common study of many questions, and the concluding of agreements concerning the construction and utilisation of rolling stock, time-tables, commercial conditions, etc. This gave birth to many international organisations differing by reason of the nature of the questions to be studied by them and their constitutions. Particularly did such organisations come into being in the period immediately following the war.

Mr. Wolf's book gives a methodical sketch of the different relations the German Railways have with other countries, based on treaties, agreements between companies, and other arrangements. He explains their origin, development and signification. In the case of the more important agreements and associations, he details their organisation and gives the text of their statutes as an appendix.

This work, which was intended in the first place to serve as a means of increasing the general knowledge of the staff of the German Railways, and therefore deals with questions of an international order, would for the same reason be of interest to railway employees of most of the European countries.

[385. (09]

Centenarul Călor Ferate (1830-1930). [The Centenary of the Railways (1830-1930)]. — One volume (6 1/4 × 9 inches) of 468 pages with numerous illustrations, published by the Rumanian Polytechnical Society. — 1930, Bucarest, F. Göbl Fil S.A , 19, Str Regala.

A hundred years ago railways were in their infancy. Who then could have foreseen their rapid growth, the great part they would play in the material and moral development of peoples, so that today, they are an essential element in our social and economic life. In order to estimate the place they hold in the present organisation of society, it is only necessary to consider the serious results, the great confusion caused by even a short and partial interruption of railway transport services.

In the course of these hundred years, the most divers resources of engineering skill have been made use of in the establishment and the working of the railways. Civil engineering has enabled the railway to extend its lines by means of the most wonderful bridges and tunnels; the science of metallurgy has been called upon to supply materials and methods of constructing rolling stock and permanent way equipment. The modern locomotive is the result of the work of who shall say how many engineers and electricians. It is impossible to enumerate all the ways in which electricity can be applied to railways. It is used for the chief safety appliances, and

is now becoming the rival of steam as the motive power of trains.

It is easy to understand that those who have devoted much of their time to the railway should have had the idea of writing its history, of analysing the characteristic phases of its development, of calling to mind the most interesting work inspired by it, of showing its influence upon the progress of industry and upon the improvement of the economic conditions of life, in short of singing the praise of the railway in writing and in pictures.

This book was written by various authors in collaboration, each one of them depicting the railway under the aspect he found most interesting and which was most familiar to him. In a single volume are united a whole series of studies, interesting in themselves, and also on account of their great variety. Some of them deal with permanent way equipment and fixed installations, such as permanent structures; others with the locomotives and rolling stock; still others chosing to deal with a more general order of ideas, studied economic or social questions, such as, for example, that in which the influence of the railway on the intellectual formation of peoples is pointed out.

The work is adorned with numerous illustrations, many of them of great artistic merit. There are photographs of famous men, such as George Stephenson and Marc Seguin. There are drawings of picturesque scenes calling to mind memorable events, such as the inauguration of lines, and of famous stations and bridges.

Throughout the work, as also in the illustrations, the authors have laid due stress on the events which in England marked the origin of railways. The last chapter is occupied with the history of the construction of the Liverpool to Manchester line. A fine engraving depicts horsemen racing a first-class passenger train pulled by a « Rocket ».

E. M.

[62. (09]

L'évolution et le développement des principales industries depuis cinquante ans (1880-1930). [**The evolution and development of the chief industries for the last fifty years** (1880-1930)]. — Special number published on the occasion of the fiftieth anniversary of the founding of the « **Génie Civil** ». One volume in-4°, 236 pages with numerous illustrations. — Published by : Administration et Rédaction du *Génie Civil*, 5, rue Jules Lefebvre, Paris (9e). (Price : 25 fr.).

To commemorate the fiftieth anniversary of its foundation, the great French technical review *Génie Civil* has devoted a special number of particular importance to the evolution of the various industries during the fifty years that this publication has been in existence. To this end, it has appealed to the most eminent experts and to persons of the highest qualifications. The volume comprises a series of more than forty remarkably informative articles on the progress which has been made during the period in question in the main branches of technology and industry.

An introduction first of all retraces the history of the foundation and development of the *Génie Civil*.

The enormous and rapid development which has been made by industry during these last fifty years is one of the most striking features of our era. Two fundamental articles are devoted to the examination of the factors which have determined this remarkable progress. In the first Mr. H. Le Chatelier deals with

the relations between science and industry. In the other, Mr. Ch. de Fréminville examines the evolution of the methods of the scientific organisation of work, the importance of which is asserting itself more and more in all problems of production. Important articles are afterwards devoted to *aviation*, the *navy*, the *mercantile marine, agriculture, chemistry*, after which we come to those which interest more particularly the railway industry. We may mention in the first place : *Le chemin de fer depuis cinquante ans* (The railways during the last fifty years), by Mr. V. Sabouret, who draws a parallel between the development of the railways in the United States and in Europe for the last fifty years, and who afterwards examines the progress made in track-laying, in the construction of locomotives and rolling stock, in signalling, in the construction of stations, and particularly shunting stations, and finally in the organisation itself of the railways. Mr. H. Parodi in *L'électrification des voies ferrées* (The electrification of railways) deals with the modern conception of railway electrification, traction systems and the present state of electrification in France. The problems of building large bridges and tunnels are considered in *Progrès dans l'art de projeter et d'exécuter de grandes voûtes en maçonnerie* (Progress in the art of designing and constructing large masonry arches), by Mr. P. Séjourné and in the article *Progrès réalisés dans les procédés de construction des souterrains* (Progress made in the methods of constructing underground works), by Mr. L. Chagnaud. Mention may also be made of the interesting papers, *Progrès des théories de la résistance des matériaux et leur application à la construction des ponts, de 1880 à nos jours* (Progress in the theories of the strength of materials and their application to bridge building, from 1880 to our time), by Mr. H. Lossier, and on the *Idées actuelles sur la résistance des matériaux* (Modern ideas on the strength of materials), by Mr. A. Caquot.

There is quite a series of technical articles which will interest just as intensely the railway engineer : *Le calcul mécanique et le calcul graphique* (Mechanical calculation and graphical calculation) (M. d'Ocagne) ; *La grande industrie électrique* (The great electrical industry) (P. Janet) ; *Electrochimie et électrométallurgie* (Electrochemistry and electrometallurgy) (H. Gall) ; *Evolution de la sidérurgie* (Evolution of the metallurgy of iron) (C. Charpy) ; *Aciers spéciaux* (Special steels) (L. Bâcle) ; *Métaux autres que le fer* (Non-ferrous metals) (L. Guillet) ; *Evolution des machines thermiques* (Evolution of heat engines) (C. Monteil) ; *Usines hydroélectriques* (Hydro-electric power stations) (D. Eydoux) ; *Progrès de la grande industrie chimique* (Progress in the great chemical industry) (C. Matignon) ; *Progrès de l'éclairage* (Progress in lighting) (H. Laurain) ; *Radioélectricité* (Radioelectricity) (A. Blondel; *Evolution de l'automobile* (Evolution of the automobile) (Petiet and Delanghe) ; *Evolution de la législation industrielle* (Evolution of industrial legislation) (H. Capitant) ; *Evolution de la législation du travail* (Evolution of the legislation of labour) (P. Razous), etc.

We have mentioned chiefly those papers which interest the science of transportation. Many other articles could still be mentioned relating to most widely different branches of industry. All of them are profusely illustrated with diagrammatic drawings and photographs. The *Génie Civil* has thus succeeded in retracing the industrial evolution of the last fifty years in a work to which the personality of the collaborators lends a historical, scientific and informational value of the first order.

A. C.